Exhibit 53

Mineral Fiber Content of Lung Tissue in Patients with Environmental Exposures: Household Contacts vs. Building Occupants

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In recent years, there has been considerable debate within the scientific community regarding the potential risks due to exposure to asbestos in nonoccupational settings.[1–6] Of particular concern is the possible risk for development of malignant mesothelioma, which is known to occur in some cases after brief or low-level exposures to asbestos.[7–10] However, only a few reports have been published concerning the determination of mineral fiber burdens within the lungs of persons with environmental (i.e., nonoccupational) exposure to asbestos.[11–13] One of us (V.L.R.) has had the opportunity to examine the mineral fiber content of lung tissue in ten cases where the only known exposure to asbestos was as a household contact of an asbestos worker or as an occupant in a building containing asbestos insulation. It is the purpose of the present report to describe the fiber burdens in these ten cases and to compare these results with the findings in various categories of occupational exposure to asbestos.

MATERIALS AND METHODS

Case Selection. Included in this report are all cases from my consultation files for which the only known exposure to asbestos was as a household contact of an asbestos worker (six cases) or as an occupant of a building containing asbestos materials (four cases), and for which lung tissue (formalin-fixed or paraffin-embedded) was available for measurement of mineral fiber content. The demographic and pathologic findings, exposure history, and asbestos body and mineral fiber concentrations in these ten cases are summarized in TABLES 1 and 2. For the six patients with malignant (diffuse) mesothelioma, previously published histologic criteria were used to establish the diagnosis on tissues obtained either at autopsy (two cases) or surgical resection (two cases) or both (two cases).[10]

Mineral Fiber Analysis. Tissue mineral fiber content was determined using the sodium hypochlorite digestion procedure, the details of which have been reported previously.[14,15] In brief, formalin-fixed lung parenchyma with a wet weight between 0.25 and 0.35 gm was minced with a clean scalpel blade and digested in 5.25% sodium hypochlorite solution (commercial bleach) with constant gentle

TABLE 1. Demographic, Pathologic, and Exposure Information and Asbestos Content of Lung in Six Household Contacts of Asbestos Workers

Case No.	Age (yr)/ Sex	Exposure	Diagnosis	AB/gm (LM)	UF/gm (SEM)
1	62/F	Wife of shipyard insulator with asbestosis; 29 yr	Pleural mesothelioma	8,200	ND
2	33/F	Daughter of insulator with asbestosis; 25 yr	Pleural mesothelioma	2,330	17,000
3	63/F	Wife of insulator with asbestosis and lung cancer; yrs	Small cell/large cell carcinoma of lung; mild asbestosis	3,670	120,000
4	59/F	Wife of insulator with asbestosis and lung cancer; 23 yrs.	Small cell carcinoma of lung; PPP	1,060	57,000
5	73/F	Wife of insulator with lung cancer and asbestosis; yrs	Bronchioloalveolar cell carcinoma of LUL	400	23,700
6	57/F	Wife of shipyard worker; 1–2 yr	Pleural mesothelioma	2	24,300

ABBREVIATIONS: AB/gm (LM) = asbestos bodies per gram of wet lung as determined by light microscopy; UF/gm (SEM) = uncoated fibers 5μ or greater in length per gram of wet lung as determined by scanning electron microscopy; PPP = parietal pleural plaques; LUL = left upper lobe; ND = not done.

agitation. The residue was collected on 0.4 μ-pore-sized polycarbonate filters, one of which was mounted on a glass slide for asbestos body quantification by light microscopy (LM) at 200× magnification. The other was mounted on a carbon disc with colloidal graphite, sputter-coated with gold, and examined by scanning electron microscopy (SEM) at a screen magnification of 1000×.[16] Fibers were defined

TABLE 2. Demographic, Pathologic, and Exposure Information and Asbestos Content of Lung in Four Occupants of Buildings with Asbestos-Containing Materials

Case No.	Age (yr)/ Sex	Exposure	Diagnosis	AB/gm (LM)	UF/gm (SEM)
7	46/M	Worked in building with ACM; 20 yr	Adenocarcinoma of lung	14	25,000
8	58/F	Teacher in building with ACM; 18 yr	Pleural mesothelioma; PPP	2.8	13,000
9	45/M	Attended school containing asbestos; 12 yr	Peritoneal mesothelioma	1.0	6120
10	53/M	Accountant in building with ACM; 18 yr	Pleural mesothelioma	<0.2	6370

ABBREVIATIONS: AB/gm (LM) = asbestos bodies per gram of wet lung as determined by light microscopy; UF/gm (SEM) = uncoated fibers 5μ or greater in length per gram of wet lung as determined by scanning electron microscopy; PPP = parietal pleural plaques; ACM = asbestos-containing materials.

as particles with an aspect ratio (length : diameter) of at least 3 : 1 and roughly parallel sides, and particles meeting these criteria and with a length of 5 μm or greater were counted. From these data, fiber density on the filter surface and numbers of fibers per filter could be determined. Asbestos bodies and uncoated fibers were enumerated separately, and results reported as asbestos bodies or uncoated fibers 5 μm or greater in length per gram of wet lung tissue.[16] In two cases (Cases 9 and 10, TABLE 2), an additional 5-gram sample of lung tissue was processed for asbestos body quantification using the technique of Smith and Naylor.[17]

In three cases (Cases 1, 3 and 4, TABLE 1), only paraffin blocks of lung parenchyma were available for analysis. In these cases, tissue was recovered from the block, deparaffinized in xylene, and rehydrated to 95% ethanol as previously described.[15,18] Digestion was then performed as described above. The filter was cut in half with a scalpel blade, and one half was mounted on a glass slide for asbestos body quantification by LM, whereas the other half was mounted on a carbon disc and examined by SEM. The results were multiplied by a correction factor (0.7), which takes into account the difference in weight between formalin-fixed lung and lung that has been processed into paraffin.[15]

The chemical composition of mineral fibers was determined by means of energy-dispersive spectrometry in nine of the ten cases. Five to thirty consecutive fibers were analyzed per case and classified as asbestiform (amosite, crocidolite, tremolite, anthophyllite, actinolite, or chrysotile) or nonasbestiform on the basis of morphology and chemical composition as previously described.[15,16]

Additional studies were performed in one case (Case 8, TABLE 2) to further characterize the mineral content of lung tissue. Paraffin-embedded lung parenchyma was deparaffinized in xylene (three changes, 2 hours each) and ashed in a low-temperature plasma asher for 100 hours. The dry weight of four combined specimens in this case was 0.18 gram. After ashing was complete, the remaining residue was suspended in 24 ml of filtered, deionized water and then sonicated for 10 minutes. The suspension was then filtered through a 0.45 μ-pore-sized mixed cellulose ester filter, which was then prepared by the direct method for examination by transmission electron microscopy, selected area electron diffraction, and energy-dispersive spectrometry (TEM/SAED/EDS).[19] Also examined with the same method was tissue obtained from five patients who had died approximately at the same time and in the same institution as Case 8. These patients had died from coronary artery disease (two cases), pulmonary embolism, carcinoma of the colon, or cirrhosis (one each). Reagent blanks were also prepared as described above, but with tissue omitted.

In addition, a plaster sample was obtained from the high school where case 8 was employed and was analyzed for its mineral content by means of polarized light microscopy with dispersion staining[20] and by TEM/SAED/EDS. Also, the weight percent soluble component was determined by dissolution in a mild hydrochloric acid solution.

RESULTS

The tissue asbestos content of the six household contacts of asbestos workers is summarized in TABLE 1. All were women with ages ranging from 33 to 73. Three of these patients had pleural mesothelioma and three had lung cancer. One of the latter also had mild asbestosis and one had parietal pleural plaques. Case 5 was a nonsmoker. The husband in four cases and the father in one case had worked as

asbestos insulators. Each had been diagnosed as having asbestosis and three also had lung cancer. The asbestos body (AB) counts among the six household contacts ranged from 2 to 8,200 AB/gm, with a median value of 1,700 AB/gm. The contents of uncoated fibers (UF) 5 microns or greater in length ranged from 17,000 to 120,000 UF/gm, with a median count of 24,300 UF/gm. In comparison, our normal range for asbestos bodies as determined in 84 cases with no evidence of asbestos exposure or an asbestos-related disease is 0–20 AB/gm.[15,16,18] The median uncoated fiber count for 20 patients with macroscopically normal lungs at autopsy and no history of asbestos exposure was 3,100 UF/gm[16] (and unpublished observations).

The tissue asbestos content of the four building occupants is summarized in TABLE 2. There were three men and one woman, with ages ranging from 45 to 58. Two of these had pleural mesothelioma, one had peritoneal mesothelioma, and one had adenocarcinoma of the lung. The latter was a nonsmoker. All four had either worked or attended school in buildings with asbestos-containing materials for periods ranging from 12 to 20 years. The asbestos body counts among the four building occupants ranged from less than 0.2 to 14 AB/gm, with a median value of

TABLE 3. Asbestos Content of Lung Tissue by Exposure Category[a]

	n	AB/gm (LM)	UF/gm (SEM)
Insulation workers	59	20,400	224,000
Shipyard workers (other than insulators)	60	3,600	37,000
Other asbestos workers	24	2,360	68,800
Household contacts	6	1,700	24,300
Railroad workers	10	55	28,800
Brakeline work or repair	8	50	15,400
Manual laborer	15	20	8,830
Other	18	2.9	2,910
Building occupants with ACM	4	1.9	9,680

[a] Data are presented as median values. For other abbreviations, see footnotes to TABLES 1 and 2.

1.9 AB/gm. All are within our normal range of 0–20 AB/gm. The content of uncoated fibers 5 microns or greater in length ranged from 6,120 to 25,000 UF/gm, with a median count of 9680 UF/gm. The latter exceeds the median count of 3,100 UF/gm found in our 20 patients with macroscopically normal lungs and no known exposure to asbestos.

TABLE 3 compares the tissue asbestos content in these 10 cases with environmental exposure with that of 161 occupationally exposed individuals and 33 with no known occupational exposure. It can be seen that in terms of asbestos body concentrations, household contacts rank fourth and have levels that are comparable to those of shipyard workers other than insulation workers and other asbestos workers (including asbestos cement workers, asbestos textile workers, chemical maintenance workers, welders, machinists, filter manufacturers, roofing plant workers, refinery workers, sheet-metal workers, and industrial workers with exposure to asbestos not further specified). Building occupants rank last with regard to asbestos body concentrations, and generally these values are the same as those in individuals with no known exposure to asbestos (including textile workers, farmers, military personnel, chemical workers, factory workers, dieticians,

TABLE 4. Energy-Dispersive Spectrometry of Fibers in Patients with Environmental Exposures

	n	Commercial Amphiboles[a]	Noncommercial Amphiboles[b]	Chrysotile	Other[c]
Household contacts	5	46 (48%)	10 (10.5%)	4 (4.2%)	35 (37%)
Building occupants	4	2 (4.4%)	9 (20%)	1 (2%)	33 (73%)

[a] Commercial amphiboles = amosite and crocidolite.
[b] Noncommercial amphiboles = tremolite, anthophyllite, and actinolite.
[c] Other = talc, silica, rutile, aluminum silicates, miscellaneous silicates, iron, and iron–chromium.

guards, musicians, salesmen, barbers, engineers, teachers, tailors, grainmill workers, building contractors, truck drivers, and office workers). Although the ranking by uncoated fiber concentration is slightly different from that for asbestos body content, the former must be considered in light of the types of fibers (asbestiform or nonasbestiform) present as determined by EDS.

The chemical composition of 95 fibers isolated from the lungs of five of the household contacts and 45 fibers isolated from the lungs of the four building occupants is summarized in TABLE 4. Almost half of the fibers from the household-contact cases were the commercial amphiboles, amosite or crocidolite, whereas fewer than 5% of the fibers from the building occupants were commercial amphiboles. On the other hand, almost three-fourths of the fibers from the building occupants were nonasbestos mineral fibers,[21,22] mostly talc, silica, rutile, and miscellaneous aluminum silicates. Noncommercial amphiboles and chrysotile accounted for a minority of fibers in both groups (15 to 22%).

Scanning electron microscopic analysis of lung tissue from Case 8 disclosed a substantial number of high aspect-ratio fibers with a chemical composition indicative of tremolite. Talc, aluminum silicate, and mica particles with a 3 : 1 or greater aspect ratio and length of 5μ or more were also identified. Further analysis of lung tissue from this case by analytical TEM confirmed the presence of talc, tremolite, chrysotile, bentonite, and perlite. These constitute five of the seven components identified in the acoustical plaster from the school where this patient was employed (TABLE 5). No more than two of these seven components were found in the lungs of the five control subjects. Additional particles found in these latter five patient's lungs included kaolinite, attapulgite, quartz, and mica.

TABLE 5. TEM/SAED/EDS Data Regarding Particulate Content of Lung in Case 8 as Compared to Five Control Subjects and Plaster from Building

	Chrysotile	Tremolite	Perlite	Talc	Bentonite	Calcite	TiO_2
Plaster	+	+	+	+	+	+	+
Case 8	+	+	+	+	+	−	−
Control A	+	−	−	+	−	−	−
Control B	−	+	−	−	−	−	−
Control C	−	−	−	−	−	−	−
Control D	−	+	−	−	−	−	−
Control E	−	−	+	+	−	−	−

NOTE: + = Present; − = not detected.

DISCUSSION

An increased risk of developing an asbestos-related disease has been reported among household contacts of asbestos workers,[2,9] presumably secondary to asbestos fibers brought home on the worker's clothing. However, there have been few reports of the analysis of pulmonary asbestos content among household contacts of asbestos workers. Whitwell *et al.*[11] described a case of mesothelioma in the son of a worker from a gas-mask factory where the workers took crocidolite home to pack into canisters. The worker's son was found to have between 50,000 and 100,000 fibers per gram of dry lung tissue as determined by phase-contrast light microscopy. (One gram of dry lung tissue is approximately equivalent to 10 grams of wet lung tissue.) Huncharek *et al.*[12] reported another case of mesothelioma in the 76-year-old wife of a shipyard machinist who dismantled boilers and other shipyard machinery for 34 years. This patient was found to have 6.5 million fibers per gram of dry lung as determined by TEM. The present study indicates that, in general, household contacts have substantially elevated pulmonary asbestos burdens, often in the range of those of individuals who are occupationally exposed to asbestos (TABLE 3). That the exposures in these women's homes were heavy is further supported by the observation that in five of the six cases, the occupationally exposed individual in the household was an insulation worker with clinically diagnosed asbestosis. Three of these individuals also had lung cancer. The median asbestos body and uncoated fiber contents of 30 insulation workers with asbestosis in the author's series are 109,000 AB/gm and 646,000 UF/gm of wet lung tissue, respectively.

There has been considerable scientific and public debate concerning possible risks of asbestos-induced disease derived from living, working, or attending school in buildings containing asbestos.[1–6] Certainly the measured air fiber levels in buildings using current methods are extremely low,[23] and no adverse health effects have been observed in at least one comparison study of workers in buildings with and without asbestos insulation.[24] However, significant levels of asbestos-contaminated dust are found in these buildings, and routine maintenance activities can disturb this dust, producing high concentrations of airborne asbestos. The present study indicates that building occupants have pulmonary asbestos burdens that are quite similar to those of individuals with no known occupational exposure to asbestos (TABLE 3), and it would be anticipated that their risks for developing an asbestos-related disease would be correspondingly low. It should be noted that exposure to asbestos as a building occupant cannot be excluded among the 18 individuals in TABLE 3 with no known occupational exposure to asbestos. However, we have no reason to believe that these individuals are anything other than representative of the background, "nonexposed" population for our area. Furthermore, not all mesotheliomas are related to asbestos exposure since spontaneous cases do occur[11] as do a few rare cases attributable to causes other than mineral fibers.[25]

There is a single case report in the literature of pleural mesothelioma developing in an individual whose only known exposure to asbestos was as an office worker in a building with asbestos-containing materials (ACM).[13] This was a 54-year-old woman who worked for many years in a building with ceiling material composed of 70% amosite asbestos. Analysis of her lung tissue demonstrated 31 million fibers per gram of dry lung by TEM, the vast majority of which were found to be amosite asbestos by EDS.[13] Our Case 8 demonstrated an unusual number of high aspect-ratio tremolite fibers within her lung parenchyma (TABLES 2 and 5). Tremolite asbestos is a recognized cause of pleural mesothelioma, accounting for

about 20% of cases according to the study by McDonald *et al.*[26] Since multiple components of the acoustical ceiling plaster from the building in which this patient worked were also found in her lung tissue samples, this is the most likely source of the tremolite asbestos fibers that were identified. There was no evidence of exposure to cosmetic talc and no evidence of household exposure on the basis of her husband's occupational history. Furthermore, the presence of histologically confirmed parietal pleural plaques is compelling evidence that this woman's pleural mesothelioma was indeed asbestos-related. Additional studies are necessary in order to determine whether such cases as these occur with sufficient frequency to be of public concern.

SUMMARY

Analysis of tissue mineral fiber content in patients with environmental exposures has seldom been reported in the past. Our studies of six household contacts of asbestos workers indicate that these individuals often have pulmonary asbestos concentrations similar to some occupationally exposed individuals. In contrast, our studies of four occupants of buildings with asbestos-containing materials indicate that these individuals often have pulmonary asbestos burdens indistinguishable from the general nonoccupationally exposed population. However, one such building occupant exposed for many years and who later developed pleural mesothelioma was studied in detail, and it was concluded that her exposure as a teacher's aide in a school building containing acoustical plaster was the likely cause of her mesothelioma.

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Exhibit 54

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Procedure for the Analysis of Talc for Asbestos

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ABSTRACT

The analysis of talc powder for asbestos is most appropriately done with a combination of polarized light microscopy (PLM), transmission electron microscopy (TEM) and in some cases a screening by X-ray diffraction (XRD). Low levels of thin asbestos fibers in talc may only be seen using the TEM analysis. Although never formally adopted by the U.S. Environmental Protection Agency (EPA), the 1993 EPA bulk method (EPA R-93) for asbestos provides the basis for the PLM portion of the method, as it is a good description of the light microscopy techniques available. The consensus method D6281 balloted and published by ASTM International provides the basis for the TEM portion of the method. The method described here has been used to investigate vintage talcum powders and talcum products currently available. Some asbestos has been found in vintage powders but with the exception of one Chinese product, asbestos was not detected in currently available powders using the talc-asbestos method described here.

Keywords: talcum, asbestos, polarized light microscopy (PLM), transmission electron microscopy (TEM), X-ray diffraction (XRD), light microscopy, National Institute for Occupational Safety and Health (NIOSH), U.S. Environmental Protection Agency (EPA), ASTM International, International Standards Organization (ISO), phase contrast microscopy (PCM), McCrone Research Institute, New York University Department of Chemistry, tremolite, chrysotile, anthophyllite, pyrophyllite, asbestiform, fibers, selected area electron diffraction (SAED), scanning electron microscopy (SEM), energy dispersive X-ray spectroscopy (EDS), Asbestos Hazard Emergency Response Act (AHERA) U.S. Pharmacopeia (USP) Talc monograph, infrared spectroscopy (IR), Walter C. McCrone, Lucy McCrone

INTRODUCTION

In 1968, Cralley et al. (1), from the Occupational Health Program, National Center for Urban and Industrial Health in Cincinnati, Ohio (predecessor of the National Institute of Occupational Safety and Health — NIOSH) reported that they had examined 22 talcum products purchased off-the-shelf (representing body powder, bath powder, and all purpose powder) for fibrous and mineral content. Cralley et al. used phase contrast microscopy (PCM) and found that all of the 22 talcum products had an appreciable fiber content that ranged from 8% to 30% by count of the total talcum particulates. Although the specific fibrous materials were not identified by PCM, XRD analysis by the authors led them to believe that the fibers were predominantly fibrous talc, with the probable presence in minor amounts of other fibrous minerals, such as tremolite, anthophyllite, chrysotile and pyrophyllite. The authors remarked that the electron microscope, with its higher power of resolution, showed a number of submicron diameter particulates not visible by means of PCM, but they did not identify any of the

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fibers by electron microscopy. The authors concluded that cosmetic talcum products should be included as a source of fibers from which may be derived ferruginous bodies observed in the lungs of humans.

A number of independent scientists were involved with analyzing talcum powders in the 1970s. Walter C. McCrone Associates, Inc., in Chicago analyzed talcum powders for various groups, including NIOSH. They used PLM, XRD and TEM in their investigations. They reported finding asbestos fibers in a number of talc samples (2–5).

At the New York University Department of Chemistry one sample of talcum powder sample (referred to as #1615) was tested in 1972 (6). They reported that their initial test by XRD showed "some features in its X-ray pattern that suggested that it might contain some tremolite" and "accordingly, the specimen was subjected to a detailed microscopic examination. Both tremolite and chrysotile fibers were found to be present in the sample. It is estimated the tremolite content is about 2% by weight, and the chrysotile about 0.5%" (6).

In 1974, Rohl and Langer (7) reported on the analysis of consumer talcum powders using analytical methods for identification, characterization and quantitation of asbestos fibers that included PLM, XRD, and TEM with selected area electron diffraction, and electron microprobe techniques. They remarked that the light microscope methods had severe limitations imposed by the ultimate size resolution of the light-optical system. They reported that small particles can go unresolved and most optical properties, e.g., refractive indices, are difficult to measure on small particles. They recommended light microscopy for use only as a preliminary tool for the analysis of consumer talc. Their detection limits for XRD analysis of consumer talcum products were as low as 0.1% by weight for tremolite, 0.25% for chrysotile but only 2.0% for anthophyllite. They concluded that the unique characterization of amphibole fibers (anthophyllite and tremolite versus fibrous talc) required TEM structural analysis (selected area electron diffraction — SAED) and micro-chemical characterization. Rohl and Langer recommended both XRD and TEM with SAED for analysis of consumer talc for their asbestos fiber content.

In another article published in 1974, Rohl (8) remarked, "Talc deposits include asbestos minerals such as chrysotile and amphiboles that may be carried over into consumer products. Optical [light] microscopy and X-ray diffraction analyses may not reveal their presence." Rohl reported that even at the detection limit for chrysotile by XRD (0.25%), there would be about a billion (10^9) fibers per mg of talc. He concluded that a sample of cosmetic talcum powder, which had been found negative for chrysotile when checked only by XRD, might contain billions of fibers that could be released during dusting with a half-gram dose.

In 1976, Rohl and Langer (9) reported on their testing of 20 consumer products labeled as "talc" or "talcum powder," including body powders, baby powders, facial talcums and one pharmaceutical talc. Of those 20 products, 10 were found to contain detectable amounts of tremolite and anthophyllite, principally asbestiform. The samples were analyzed by XRD, PLM, scanning electron microscopy (SEM) and TEM equipped with energy dispersive X-ray spectroscopy (EDS) and SAED capabilities. The authors noted that while some asbestos was resolvable by light microscopy, most samples were too fine-grained, with particle dimensions too small for light microscopy. By comparing the results of PLM and quantitative XRD with those from TEM analysis, they noted that large numbers of fibers could go undetected when using only the less sensitive techniques of PLM and XRD.

In 1990, Kremer and Millette (10) published a TEM procedure for the analysis of powdered talc for asbestos that had been in use in the McCrone laboratory in Atlanta since 1985. The method began by preparing an aqueous suspension of talc treated with the wetting agent, methylcellulose. Particles were transferred to a TEM grid via the "drop mount" method, where a drop of the talc-water suspension is placed on a carbon-coated formvar grid. Asbestos fibers were identified based on morphology as seen in the TEM, crystal structure as determined by SAED and elemental composition using an EDS system. Elongated particles with parallel sides and an aspect ratio of greater or equal to 3:1 were counted. Fibrous particles that needed to be distinguished from asbestos were listed as enrolled talc, ribbon talc, antigorite, talc fragments, silica and iron oxide fibers, and organic additives such as perfumes that may crystallize as fibers or needle-shaped crystals. The published method had a theoretical detection limit of 0.00005% (10^{-5}) weight percent based on a fiber 3 µm long by 0.2 µm wide by 0.06 µm thick as an asbestos fiber thought to be representative at the time of the smaller asbestos fibers found in some talc.

For lack of better statistical information at the time in 1990, the publication stated a rule of thumb that the detection of five or more asbestiform minerals of one variety in an analysis constituted a quantifiable level of detection. Subsequent method development in the area of TEM analysis for asbestos has shown that the detection of less than five fibers in a sample can provide a statistically valid result.

Although SEM is used to monitor asbestos in several European countries, it is not accepted in the U.S. for any analysis method of asbestos in talc. Davis, 1991 (11) tried to use the SEM to differentiate asbestos fibers from non-asbestos fibers. They reported: "This proved impracticable to do subjectively with any degree of reproducibility and had to be abandoned…" (11).

EXISTING METHODS FOR TALCUM POWDERS

The two historical methods for the analysis of talcum powders for asbestos are known as the CTFA-J4-1 (12) and USP-Talc (13). They are not considered up-to-date and are in need of revision.

The CTFA-J4-1 stands for the "Cosmetic, Toiletry and Fragrance Association method for Asbestiform Amphibole Minerals in Cosmetic Talc" first published in 1971. Part 1 is an XRD method. If an amphibole mineral is detected at a level greater than 0.5%, then the sample must be analyzed by Part 2 using (light) microscopy coupled with dispersion staining. To be counted, the fibers must have at least a 5:1 aspect ratio, be less than 3 µm in diameter and less than 30 µm in length. The document states that TEM with SAED offers greater sensitivity, but that it was not included because it was not thought to be suitable for normal quality-control application (based on time of analysis, expertise required and expense of equipment).

USP-Talc refers to the existing U.S. Pharmacopeia (USP) talc monograph published before 1983, which includes a test for "Absence of Asbestos." The asbestos test (which is currently pending revision) began with either an infrared spectroscopy (IR) test (USP-191) or an XRD test (USP-941). If the result of the IR or XRD test is negative, then no further analysis is required. If the IR or XRD test option gives a positive result, then an optical microscopy test (USP-776) must be done to confirm asbestos. The optical microscopy procedure does not require the use of polarized light.

SUMMARY OF A METHOD FOR THE ANALYSIS OF TALCUM POWDER FOR ASBESTOS

The method for the investigation for asbestos in talc described here is based on the early work of Walter and Lucy McCrone, the work of Kremer and Millette published in 1990 and the subsequent asbestos analytical procedures for PLM developed for the EPA, and the TEM methods standardized and published by the ASTM International (formerly American Society for Testing and Materials).

In the asbestos-talc method presented here, the sample is initially examined under a stereomicroscope at magnifications ranging from 7X to 40X. Portions of the particulate found in the sample are mounted in appropriate Cargille refractive index liquids for analysis by PLM using a polarized light microscope with a magnification range from 100X to 1,000X. The PLM analysis follows the procedures for bulk analysis of building materials described in the EPA 1993 bulk method (14). General SEM imaging of the sample using a scanning electron microscope can be done as an option to judge the extent of fibers in the sample. As a screening, XRD analysis is performed by scanning over a range of 3° to 45° 2Θ using 40kV, 25mA Cu Kα radiation. Mineral phases are identified with the aid of computer-assisted programs accessing a CD-ROM powder diffraction database. Mineral concentrations are based on relative peak heights and reference intensity ratios.

A transmission electron microscope equipped with EDS X-ray analysis system and capable of SAED is used to analyze the talc and asbestos fibers in the sample including tilting of talc/anthophyllite fibers. The TEM asbestos fiber counting criteria of fibers greater than 0.5 micrometer in length with at least a 5:1 aspect ratio as described in the Asbestos Hazard Emergency Response Act (AHERA) (15) and ASTM methods: D6281 (16), D5755 (17), D5756 (18) and D6480 (19) as well as in ISO 10312 (20) and 13794 (21) are used. The d-spacing/interfacial angle tables of Shu-Chun Su (22) are used when the option to index zone-axis patterns of amphibole minerals obtained by SAED in the TEM is chosen. The results of the TEM analysis are recorded using the procedures described in ASTM D6281.

TEM NOTES

The procedures for counting asbestos fibers with TEM described in ASTM D6281 and ISO 10312 (which are essentially the same) are the most fully developed of any of the TEM methods. The major difference between ASTM D6281 and ISO 10312 is that D6281 contains inter-laboratory precision data. Both methods have been vetted, debated and approved through the ASTM International or International Standards Organization procedures involving multiple ballots by experienced and knowledgeable scientists. Although ASTM D6281 and ISO 10312 were published as methods for asbestos in air, the basic counting procedures are the same for any sample once that sample material has been placed on a TEM grid. Since they are the most developed methodologies and have been accepted internationally, D6281 was chosen as the basis for the TEM part of this talc analysis method.

TABLE 1 Examples of the Minimum Number of Grid Openings Required to Achieve a Particular Analytical Sensitivity for a Collection Filter Area of 385 mm² and TEM Grid Openings of 85 µms (0.0072 mm²)

Analytical Sensitivity	Volume of Air Sampled, L						
Structures/L	500	1000	1200	2000	3000	4000	5000
0.1	1066	533	444	267	178	134	107
0.2	533	267	223	134	89	67	54
0.3	356	178	148	89	60	45	36
0.4	267	134	112	67	45	34	27
0.5	214	107	89	54	36	27	22
0.7	153	77	64	39	26	20	16
1.0	107	54	45	27	18	14	11
2.0	54	27	23	14	9	7	6
3.0	36	18	15	9	6	5	4
4.0	27	14	14	7	5	4	4
5.0	22	11	13	6	4	4	4
7.0	16	8	7	4	4	4	4
10.0	11	6	5	4	4	4	4

Figure 1. Table 1, reprinted from ASTM D6281-09 Standard Test Method (16), contains examples of the minimum number of grid openings required for certain analysis situations, ranging from four to 1,066 openings.

In both ISO 10312 and D6281 methods, one sentence has been interpreted by one scientist as indicating that the method is presumptive of asbestos present. The claim is that the fibers determined during the analysis using the method cannot be considered to be asbestos unless bulk analysis has been performed previously and asbestos identified in a product. This is not the case. The sentence contains two independent phrases that describe the applicability of the method. The first phrase describing the application of the method is for "the measurement of airborne asbestos in a wide range of ambient air situations." This expression is general, and there is absolutely no suggestion contained within it that asbestos is presumed to be present or presumed to be absent. The second phrase in the sentence is "for detailed evaluation of any atmosphere in which asbestos structures are likely to be present." This second phrase was intended to show an example of one of the many types of situations where the method might be used. D6281 is applicable for a detailed evaluation of any atmosphere for asbestos.

Number of Grid Openings to Be Counted

It is clear from examination of the equation used to calculate the concentration of asbestos fibers in a sample that the level of analytical sensitivity improves with the number of grid openings analyzed. ASTM D6281 does not specify a maximum number of grid openings that should be examined. Table 1 (see Figure 1) of D6281 contains examples of the minimum number of grid openings required for certain analysis situations that range from four to 1,066 openings. While the "rule of thumb" guideline of using 10 full-grid openings represents a judicious compromise between a reasonable experimental effort and a fairly low value of the detection limit, using two or more TEM grids (to analyze more grid openings) reduces the detection limit further and improves the precision of the estimates (23).

Differentiation of Asbestos Fibers from Non-asbestos Fibers

In 1990, Wylie (24) published some suggested characteristics of a population of particles with the asbestiform mineral habit. These included a mean aspect ratio of 20:1 or greater for fibers longer than 5 µm. Asbestos was characterized by very thin fibrils, usually less than 0.5 µm in width, and two or more of the following:

- Parallel fibers occurring in bundles
- Fiber bundles displaying splayed ends
- Fibers in the form of thin needles
- Matted masses of individual fibers
- Fibers showing curvature

Subsequently, the draft EPA R-93 (14) repeated most of the characteristics in a glossary providing a definition of a population of asbestos fibers as observed with light microscopy in a bulk sample. The EPA draft deleted the characteristic of fibers in the form of thin needles as being indicative of asbestiform.

TABLE 2-2. OPTICAL PROPERTIES OF ASBESTOS FIBERS

Mineral	Morphology and Color[1]	Refractive Indices[2] α	Refractive Indices[2] γ[5]	Birefringence[6]	Extinction	Sign of Elongation
Chrysotile (asbestiform serpentine)	Wavy fibers. Fiber bundles have splayed ends and "kinks". Aspect ratio typically >10:1. Colorless[3]	1.493-1.546 1.532-1.549 1.529-1.559 1.544-1.553	1.517-1.557 1.545-1.556 1.537-1.567 1.552-1.561	0.004-0.017	Parallel	+ (length slow)
Amosite (asbestiform grunerite)	Straight to curved, rigid fibers. Aspect ratio typically >10:1. Colorless to brown, nonpleochroic or weakly so.[4] Opaque inclusions may be present	1.657-1.663 1.663-1.686 1.663-1.686 1.676-1.683	1.699-1.717 1.696-1.729 1.696-1.729 1.697-1.704	0.021-0.054	Usually parallel	+ (length slow)
Crocidolite (asbestiform riebeckite)	Straight to curved, rigid fibers. Aspect ratio typically > 10:1. Thick fibers and bundles common, blue to dark-blue in color. Pleochroic.	1.693 1.654-1.701 1.680-1.698	1.697 1.668-1.717 1.685-1.706	0.003-0.022	Usually parallel	- (length fast)
Anthophyllite-asbestos	Straight to curved fibers and bundles. Aspect ratio typically > 10:1. Anthophyllite cleavage fragments may be present with aspect ratios <10:1. Colorless to light brown.	1.598-1.652 1.596-1.694 1.598-1.674 1.6148[7]	1.623-1.676 1.615-1.722 1.615-1.697 1.6362[7]	0.013-0.028	Parallel	+ (length slow)
Tremolite-Actinolite-asbestos	Straight to curved fibers and bundles. Aspect ratio typically > 10:1. Cleavage fragments may be present with aspect ratios <10:1. Colorless to pale green	Tremolite 1.600-1.628 1.604-1.612 1.599-1.612 1.6063[7] Actinolite 1.600-1.628 1.612-1.668 1.613-1.628 1.6126[7]	Tremolite 1.625-1.655 1.627-1.635 1.625-1.637 1.6343[7] Actinolite 1.625-1.655 1.635-1.688 1.638-1.655 1.6393[7]	0.017-0.028 0.017-0.028	Parallel and oblique (up to 21°); Composite fibers show parallel extinction.	+ (length slow)

[1]Colors cited are seen by observation with plane polarized light.

[2]From references 2, 11, 12, and 18, respectively. Refractive indices for n_a at 589.3nm.

[3]Fibers subjected to heating may be brownish. (references 13, 14, and 15)

[4]Fibers subjected to heating may be dark brown and pleochroic. (references 13, 14, and 15)

[5]∥ to fiber length, except ⊥ to fiber length for crocidolite only.

[6]Maximum and minimum values from references 2, 11, 12, and 18 given.

[7]± 0.0007

Figure 2. Table 2.2, reprinted from EPA Test Method R-93 (14), suggests using an aspect ratio of 10:1 in distinguishing between asbestos and non-asbestos fibers when considering optical properties.

Although these mineralogical population characteristics serve as a useful index in screening products and materials that contain fibers that might cause asbestos disease, the criteria are not very useful when dealing with individual fibers. The characteristics of parallel fibers occurring in bundles, fiber bundles displaying splayed ends, matted masses of individual fibers and fibers showing curvature are not related to the disease causing potential of asbestos fibers. Microscope analysis of individual fibers found on air sample filters produced from standard reference amosite (grunerite) asbestos fibers found very few parallel fibers occurring in bundles, fiber bundles displaying splayed ends, matted masses of individual fibers or fibers showing curvature. Trying to use two or more of those mineralogical characteristics would result in misclassifying up to 80% of the asbestos fibers.

The aspect ratio (AR) of a fiber, as determined by dividing its length by its width, has been used in discriminating between asbestos and non-asbestos fibers. Table 2.2 (see Figure 2) in the draft EPA R-93 method suggests using an aspect ratio of 10:1 in distinguishing between asbestos and non-asbestos fibers when considering optical properties. However, while research has shown that a population of cleavage fragment particles has a smaller average AR than a population of commercial asbestos fibers, the AR distributions of the two populations overlap, and on an individual basis, some fibers can be classified either way. Research by Wylie (25) reported in 1985 showed that 50% of the fibers in a known amosite (grunerite) asbestos sample would not be counted if a 20:1 aspect ratio were used as a criterion. Comparison of the aspect ratio plots in the 1977 Bureau of Mines Circular (26) shows that a criterion of about 5:1 aspect ratio appears to be the best aspect ratio discriminator for asbestos versus non-asbestos fibers. The 5:1 aspect ratio is used in AHERA; ASTM methods D6281, D5755, D5756 and D6480; and ISO 10312 and 13794.

The width of the fiber was found in inter-laboratory testing by Harper (27) to be the best discriminator for asbestos fibers, and that using a criterion of width that is less than or equal to one micrometer provides the least number of false negatives when dealing with asbestos and non-asbestos fibers. At the time of this writing, this information has not been incorporated into any standard method.

Elemental Analysis

The X-ray elemental spectrum collected from individual fibers is compared to data collected from known asbestos minerals. It is noted that the elemental compositions of talc and anthophyllite can be very similar. Although NIST-standard anthophyllite contains a small amount of iron, end-member anthophyllite, which contains very low or non-detectable amounts of iron, is reported in a standard mineralogical text (28) and documented in at least one talc deposit (29).

Zone Axis Indexing

Using ASTM D6281 allows for the option of indexing a portion of the SAED patterns and then comparing the values determined to calculated zone axis values. This is not possible with all fibers. Method D6281 (or any other TEM asbestos method) does not dictate the tolerance required for a positive match between observed and calculated values. Because of the known variability among the same mineral types found in different sources, it has been suggested that a tolerance of 10% might be used. Testing in the 1970s at the EPA research laboratory of chrysotile asbestos fibers from many sources showed that 5% tolerance was necessary when matching chrysotile asbestos SAED "d" values for the (002), (110) and inter-row spacing to account for the variability between different chrysotile fiber sources. This 5% criterion has been the standard taught during TEM asbestos analysis classes since 1987. This value is in line with early XRD data such as the 3.43% difference between the observed talc (002) measurement of 9.278 angstroms when compared to the calculated value of 8.96 angstroms by Gruner (30) and the 4.24% difference in the measured value for talc (002) by Gruner (30) of 8.960 angstroms and that measured by Stemple (31) of 9.34 angstroms. Table 4 (see Figure 3) in the draft Yamate document (23) shows a 16% difference between the d_1 of the SAED Internal Standard File Data and the d_1 from the X-ray Powder Diffraction File Data for the [101] zone axis for crocidolite (XRD File Index: 19-1061).

Talc Pseudo-Hexagonal Pattern

Table 4 in the draft Yamate document (23) lists [–1 4 2] as a reference zone axis for anthophyllite. With d_1 and d_2 both at 4.56 angstroms and an angle of 60°, this pattern is very close to the zone axis measured on a typical pseudo-hexagonal pattern obtained from a talc plate. Therefore, a fiber cannot be considered to be anthophyllite on the basis of a zone axis index match of the [–1 4 2] alone. Fortunately, a talc fiber can be differentiated from an anthophyllite fiber because the talc pattern remains evident as the talc particle is tilted, but the pattern changes when an anthophyllite fiber is tilted.

TABLE 4. COMPARISION OF d-SPACINGS FROM SAED FILE AND POWDER DIFFRACTION FILE (EXAMPLE)

		Internal Standard File Data				Powder Diffraction File Data (1975)		
Amphibole type	Zone axis	d_1 (Å)	d_2 (Å)	θ (deg)	Interrow spacing, R (Å)	d_1 (Å)	d_2 (Å)	File index no.
Amosite	[100]	5.3	9.14	90.0	5.3	5.22	9.20	17-725
	[30$\bar{1}$]	1.79	9.26	84.0	—	1.76	9.20	17-725
	[101]	4.88	9.23	74.0	5.17	4.84	9.20	17-725
	[$\bar{1}$01]	4.14	9.11	78.0	4.21	4.10	9.20	17-725
	[$\bar{3}$10]	5.22	5.13	95.0	—	5.22	5.12	17-725
Crocidolite	[100]	5.22	8.97	90.0	5.22	5.20	9.02	19-1061
	[101]	4.94	9.05	75.0	5.19	5.89	9.02	19-1061
	[$\bar{1}$10]	4.79	8.19	79.0	5.23	4.89	8.40	19-1061
	[30$\bar{1}$]	1.75	8.97	83.5	—	1.76	9.02	19-1061
	[$\bar{3}$10]	5.12	5.12	96.0	—	—	—	19-1061
Tremolite	[100]	5.04	9.03	90.0	—	5.07	8.98	13-437
	[101]	4.83	9.03	75.0	—	4.87	8.98	13-437
	[$\bar{2}$0$\bar{1}$]	2.59	8.97	80.5	—	2.59	8.98	13-437
	[30$\bar{1}$]	1.72	8.98	83.5	—	1.69	8.98	13-437
Anthophyllite	[100]	—	—	90.0	5.24	5.28	8.90	9-455
	[$\bar{1}$42]	4.56	4.56	60.0	—	4.50	4.50	9-455

Figure 3. Table 4, reprinted from the EPA Draft Report Contract #68-02-3266 by Yamate et al. (23), shows a 16% difference between the d_1 of the SAED Internal Standard File Data and the d_1 from the X-ray Powder Diffraction File Data for the [101] zone axis for crocidolite (XRD File Index: 19-1061).

Fibers with Kinks

When using the zone-axis indexing option, a few rare fibers with kinks in them that would normally be dismissed as talc ribbons by morphology may show a zone axis that match anthophyllite. Because the crystal structure matches anthophyllite and the fiber has substantially parallel sides for the majority of the fiber length, the fiber is counted as anthophyllite in this method.

RESULTS FROM USING THIS TALC METHOD

The method described here has been used to analyze both vintage talcum powders and some currently available. The analyses of samples of one brand of vintage talcum powder by this method showed the presence of asbestos fibers was described in Gordon (32). Analyses of one modern talcum powder product and a set of current cosmetic talc source samples from one

supplier using the same method did not detect any asbestos present. These later findings with the modern talcum powder are consistent with the results of a recent FDA sponsored study. During 2011–2012, the FDA contracted with AMA Analytical Services, Inc. to examine 28 cosmetic-grade talc samples from four suppliers and examine 34 off-the-shelf cosmetics for asbestos (33). Samples were received from suppliers who voluntarily sent samples; off-the-shelf samples were purchased directly from various stores based on a list of products determined by the FDA. AMA used a modified version of the New York State ELAP method 198.6/198.4 (non-friable bulk samples by PLM and TEM [34, 35]). AMA did not detect asbestos in any of the 28 talcs provided in 2011 from the suppliers or in 34 the talc-containing cosmetic products that were purchased in stores during the same period. In fact, AMA reported that all the talc materials tested contained only talc plates and no fibrous particles. Therefore, no specific testing procedures such as dispersion staining for PLM or SAED/EDS for TEM were needed. The limit of detection for the PLM portion of the AMA testing was based on one point out of 400 points multiplied by any loss during gravimetric reduction. Because there wasn't much loss for talcum powder samples, the PLM detection was reported as "around 0.21% to 0.23%." The AMA reported a limit of detection for TEM of "about 0.0000020% to 0.0000030%" based on the equation: (EFA x DF x M)/(AA x IM), where M was the mass of the smallest countable chrysotile asbestos fiber (1.60 x 10–15 grams), EFA was the effective filter area, DF was the dilution factor, AA was the area analyzed and IM was the initial sample mass. The result of the equation was multiplied by 100, to convert it to a percentage.

DISCUSSION

The methodology presented here updates the 1990 publication by Kremer and Millette and provides some information that may be helpful in updating the USP talc method. The analysis of talc powder for asbestos is most appropriately done with a combination of PLM, TEM and in some cases a screening by XRD. Low levels of asbestos fibers in talc, especially those too thin to be seen by light microscopy, may only be seen using the TEM analysis.

In 2014, Block et al. (36) discussed the modernization of the asbestos testing required in the USP talc monograph. The U.S. Food and Drug Administration (FDA) through the FDA Monograph Modernization Task Group asked the USP and National Formulary (USP-NF) to modernize the USP talc monograph in November 2010. This FDA request included updating the monograph to assure that talc used for cosmetic and pharmaceutical products is not sourced from mines that are known to contain asbestos, and asked that USP consider revising the current tests for asbestos to ensure adequate specificity. The expert panel that was charged with modernizing the USP talc monograph by the USP-NF recommended that the revision of the test for "Absence of Asbestos" omit the IR test and include a revised XRD procedure, in combination with one or more microscopic evaluations (PLM, TEM or SEM). The expert panel determined that the IR and XRD methods, as currently written, could lead to false-negative results, which could allow talc samples with asbestos contamination to pass. The panel also found that even with the additional light optical microscopy test (which currently does not include PLM), the analyst could not rule out the presence of hazardous fibers in the talc sample. In addition, the lack of identification procedures in the light optical microscopy section could lead to false-positive results. The 2014 report concluded that there was a need to modernize the current USP monograph because both the IR and the XRD methods have relatively high detection limits for asbestos, and there is no known "safe" level of asbestos exposure.

DISCLOSURE

The author has worked for both plaintiffs and defendants in lawsuits involving asbestos contamination. No client funds were received for the writing of this research article.

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36. Block, L.H.; Beckes, D.; Ferret, J.; Meeker, G.; Miller, A.; Osterberg, R.; Patil, D.; Pier, J.; Riseman, S.; Rutstein, M.; Tomaino, G.; Van Orden, D.; Webber, J.; Medwid, J.; Wolfgang, S. and Moore, K. "Modernization of Asbestos Testing in USP Talc," *Stimuli to the Revision Process. U.S. Pharmacopeia,* 2014; available online at http://www.usppf.com/pf/pub/dat/vdata/v404/GEN_STIMULI-404-s201184.html (accessed April 2015). ■

MICROSCOPY COURSES

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a not-for-profit corporation

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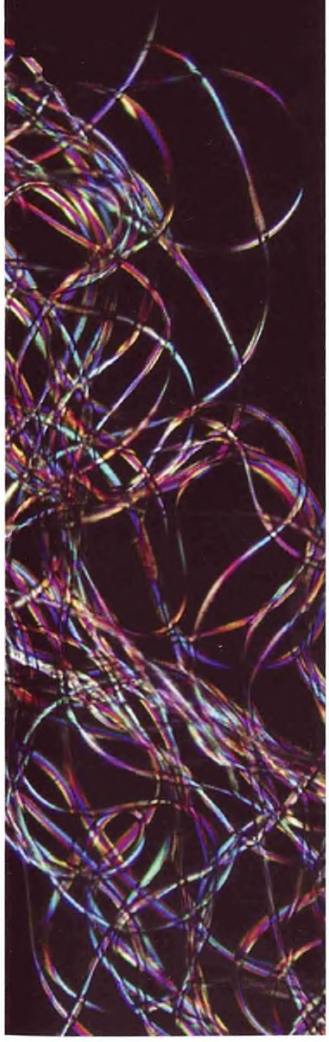

FEATURED MCCRONE MICROSCOPY COURSES

Advanced Asbestos Identification
July 20–24, 2015
In this advanced course, using polarized light microscopy (PLM), students learn to identify and differentiate among all asbestos fibers and fibrous substitutes through review of basic theory and inclusion of more advanced methods.

Forensic Dust Analysis
July 27–31, 2015
This introduction to dust trace evidence begins with the history of dust analysis and the work of Locard, Popp, Schneider, Heinrich, Frei-Sulzer and others. The course will also explore techniques for collecting, separating, analyzing and interpreting dust evidence.

Sample Preparation and Manipulation for Microanalysis
July 27–31, 2015
The course will consist of lectures, demonstrations and hands-on training in a variety of techniques of small-particle handling. Students are welcome to bring problems and samples for discussion, practice and analysis.

Advanced Indoor Air Quality: Advanced Fungal Spore Identification
August 19–21, 2015
This course is designed for working analysts with moderate experience and goes beyond the basics to deal with the problems encountered on the job. It identifies less common ascospores, basidiospores, mitospores and other spores using current and classic mycological literature. Some important genera such as Cladosporium and Aspergillus will be examined at the species level.

Microscope Cleaning, Maintenance and Adjustment
August 26–27, 2015
Students will learn how the microscope works, various approaches to lens cleaning, Köhler illumination adjustment and other tricks of the trade. Lectures will be followed by hands-on adjustment and cleaning.

Animal Hair Identification
September 1–3, 2015
This course begins with an introduction to mammalian taxonomy, and the importance of establishing reference collections and hair atlases. The structural, morphological and anatomical features of hairs will also be covered.

Digital Imaging and Photomicrography
September 14–16, 2015
Students will learn how to capture better photomicrographs and use digital processing techniques to improve them. The course covers important aspects of digital imaging microscopy, including camera and microscope hardware, system set-up, user settings, collection of quality images, storage and printing.

Raman Microscopy
September 28–30, 2015
Emphasis is placed on applications of Raman that arise from its ability to characterize molecular structure, its general ease of use and minimal sample preparation requirements. Non-routine applications will also be discussed.

Visit *www.mcri.org* for a complete course calendar, full course descriptions and online registration.

Exhibit 55

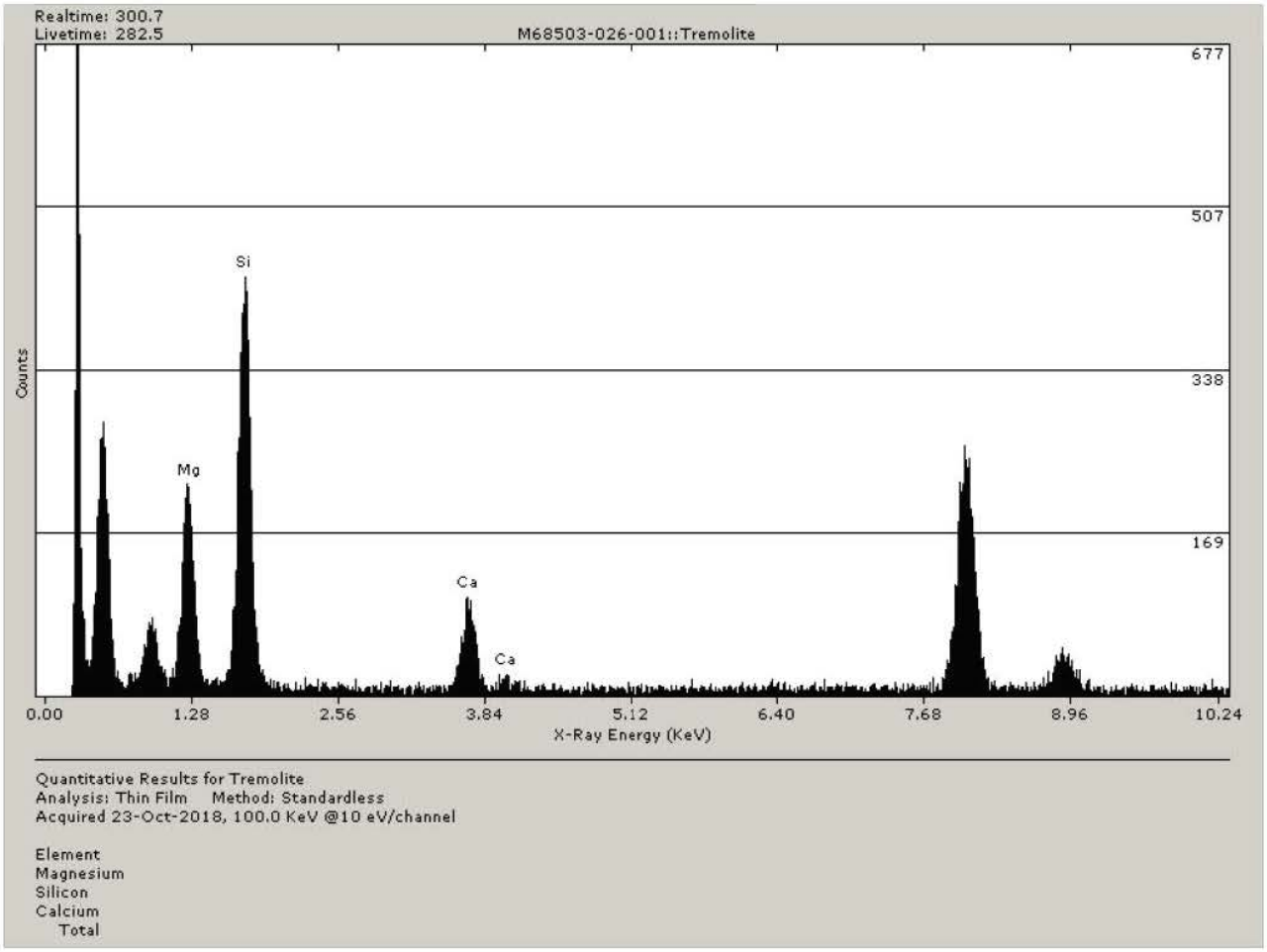
Realtime: 300.7
Livetime: 282.5
M68503-026-001::Tremolite
677
507
338
169
Counts
Si
Mg
Ca
Ca
0.00
1.28
2.56
3.84
5.12
6.40
7.68
8.96
10.24
X-Ray Energy (KeV)
Quantitative Results for Tremolite
Analysis: Thin Film Method: Standardless
Acquired 23-Oct-2018, 100.0 KeV @10 eV/channel
Element
Magnesium
Silicon
Calcium
Total

Exhibit 56

UNITED STATES DISTRICT COURT
DISTRICT OF NEW JERSEY

IN RE: JOHNSON & JOHNSON TALCUM POWDER PRODUCTS MARKETING SALES PRACTICES AND PRODUCT LIABILITY LITIGATION	)	MDL 16-2738 (FLW)(LHG)
THIS DOCUMENT PERTAINS TO ALL CASES	)	

TUESDAY, APRIL 2, 2019

– – –

Videotaped deposition of Melinda Darby Dyar, Ph.D., held at the offices of SKADDEN, ARPS, MEAGHER & FLOM, LLP, Four Times Square, New York, New York, commencing at 9:03 a.m., on the above date, before Carrie A. Campbell, Registered Diplomate Reporter and Certified Realtime Reporter.

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LIZZY HARRISON, Motley Rice

VIDEOGRAPHER:
HENRY MARTE,
Golkow Litigation Services

– – –

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EXHIBITS

(Exhibits attached to the deposition.)

MS. O'DELL: I just have an objection before the deposition starts.

Yesterday at 5:50 we received a production of new materials, approximately 140 pages of new data that we had not been provided previously. We've not had an opportunity to review and analyze that data, and based on the late production, we will move to keep this deposition open and continue it after we've had an opportunity to do so.

MR. CHACHKES: And obviously we disagree. And you'll have the opportunity to ask the witness about those documents, and you'll find there's no reason to keep anything open.

MS. O'DELL: We'll see.

MR. FINCH: We'll see.

MS. O'DELL: We'll reserve the right to take that to Judge Pisano if we can't reach an agreement.

VIDEOGRAPHER: Okay. We are

now on the record. My name is Henry Marte. I'm a videographer with Golkow Litigation Services.

Today's date is April 2, 2019, and the time is 9:03 a.m.

This videotaped deposition is being held at 4 Times Square, New York, New York, in the Matter of Talcum Powder Litigation.

The deponent today is Dr. Melinda Darby Dyar.

Will all appearances please introduce themselves for the record.

MR. FINCH: Yes. Nate Finch for various ovarian cancer victim plaintiffs.

MR. GEIER: Dennis Geier for the plaintiffs.

MS. HARRISON: Lizzy Harrison, Motley Rice.

MS. O'DELL: Leigh O'Dell on behalf of the plaintiff steering committee.

MR. LOCKE: Sorry.

MR. CHACHKES: Yeah. Alex

Chachkes on behalf of J&J, Orrick Herrington.

MR. FROST: Jack Frost, Drinker Biddle and Reath, on behalf of Johnson & Johnson.

MS. SHARKO: Susan Sharko, Drinker Biddle, same.

MS. WUNDERLICH: Sandra Wunderlich, Tucker Ellis, on behalf of PTI Royston and PTI Union.

MR. LOCKE: Tom Locke for the Personal Care Products Council.

VIDEOGRAPHER: Okay. Will the court reporter please administer the oath to the witness.

MELINDA DARBY DYAR, Ph.D., of lawful age, having been first duly sworn to tell the truth, the whole truth and nothing but the truth, deposes and says on behalf of the Plaintiffs, as follows:

DIRECT EXAMINATION

QUESTIONS BY MR. FINCH:

Q. Good morning, Ms. Darby Dyar.

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My name is Nate Finch. I introduced myself off the record to you. As I said before, I represent various ovarian cancer victim plaintiffs.

Have you ever had your deposition taken before?

A. No.

Q. Have you ever testified in a courtroom before?

A. No.

Q. Have you ever done what's called a mock deposition, where someone videotapes you and asks you questions as if you were being deposed or testifying in court?

MR. CHACHKES: So I'm going to object on work product grounds.

You can answer to the extent it's not anything you've done with counsel in this case.

THE WITNESS: Correct, it's not anything I've ever done with counsel in this case.

QUESTIONS BY MR. FINCH:

Q. So never done it your entire

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life, or you've done it in this case?

MR. CHACHKES: So the objection was don't talk about what we did in this case, but you're welcome to talk about other stuff.

THE WITNESS: No, I've never done it ever before.

QUESTIONS BY MR. FINCH:

Q. So am I correct that you have never been recognized by a court as an expert in anything? Is that correct?

A. That is correct.

Q. What is Palouse Minerals, LLC?

A. It is an LLC entity that I created for the purposes of -- on the basis of the recommendation of my personal lawyer.

Q. Created for the purposes of what, receiving funds that you earn as an expert witness?

Is that one of the reasons you created it?

A. I do considerable consulting for NASA, and I decided it would be useful to have an entity that I could consolidate my non-Mount Holyoke and non-planetary science

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income into.

Q. How long has Palouse Minerals been in existence?

A. A couple months.

Q. In what state was it formed? What's the --

A. Massachusetts.

Q. So it's a Massachusetts LLC?

A. Yes.

Q. And what's the business address for it?

A. 161 Chestnut Street in Amherst, Mass.

Q. Is that the same as your office address?

A. Yes, it is.

Q. Is it --

A. To which office are you referring?

Q. Or which office does it correspond to?

A. It corresponds to my home office.

Q. So it's your home address as well?

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A. Correct.

Q. Are you the -- the sole member of Palouse Minerals, LLC, meaning the sole person that has an ownership stake in it?

A. Yes.

Q. There are no other -- are there any other limited partners that receive an income distribution or other distribution for Palouse Minerals?

A. No.

Q. Does it have any employees?

A. Other than me, no.

Q. When were you first contacted by someone -- let me back up.

Who are you working for in connection with this case in which your deposition is being taken today?

A. I'm not exactly sure what you mean.

Do you mean who do I send the bills to?

Q. Well, you're being compensated for your time, I assume, correct?

A. Correct.

Q. All right. And you send the

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bills to Tucker Ellis. That's a law firm; is that correct?
A. I believe so.
Q. And do you have an understanding as to what party in this litigation you are serving as an expert witness for?
A. Yes.
Q. All right. Who are you working for?
A. So the checks come from Orrick, and Orrick is hired by Johnson & Johnson.
Q. Are you working for any other party to this litigation, other than Johnson & Johnson or Johnson & Johnson Consumer, Inc., or any other Johnson & Johnson subsidiary?
A. No.
Q. So you're not being compensated or doing any work with a company called Imerys, for example?
A. No.
MR. FINCH: Lizzy, can I have the notice of deposition?
(Dyar Exhibit 1 marked for

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identification.)
QUESTIONS BY MR. FINCH:
Q. Ma'am, I've put what's been marked as Darby Dyar Exhibit 1 in front of you.
Have you ever seen this or discussed it, the subject matters of what it is, with anyone?
A. Yes and yes.
Q. And what is your understanding of what this is?
A. It's a notice that I'm going to testify today, and these are the documents that are related to the case.
Q. Okay. When were you first contacted by someone on behalf of Johnson & Johnson to do work for it in connection with these cases?
A. I don't remember exactly, but sometime last fall after school started.
Q. Okay. And am I correct that your time is billed out at $500 an hour?
A. That is correct.
Q. And has anyone else from Palouse Minerals done work in connection with

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this expert engagement other than you?
A. No.
Q. The reason I ask that question, on the invoices that were produced yesterday evening, there are a couple of instances where there's redactions and the person was -- the person or entity was redacted, and that led me to believe there might have been someone else other than you who worked on the report.
MR. CHACHKES: Objection.
THE WITNESS: No one else but me worked on the report.
QUESTIONS BY MR. FINCH:
Q. Okay. What were you asked to do by Johnson & Johnson or its lawyers?
A. I was asked to review the methodology used by Drs. Longo and Rigler in a series of reports.
Q. Anything else?
A. I was asked to write a report giving my review.
Q. What methodology did you follow in analyzing Dr. Longo and Rigler's reports?
A. Well, I've been a reviewer of

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scientific documents for almost 40 years, and so I used the same methodology I'd use for reviewing a scientific paper or a proposal or any kind of report that comes across my research interests.
So I first read the report carefully, every word. Then I looked at all of the math and all the numbers and analyzed the numbers. Then I sought out all of the references that were cited in those reports and tried to read all of them. And then I looked at the report many times and tried to see if the information in the report justified the conclusions.
Q. Did you test any talc that was the source of Johnson's baby powder or SHOWER TO SHOWER® yourself?
A. No.
Q. Did you test any talc that was mined either in Italy or Vermont or China for the purposes of analyzing whether or not it contained asbestos or asbestos fibers?
A. No.
Q. Did you review any internal documents of Johnson & Johnson that indicated

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the results of its testing of either its baby powder or SHOWER TO SHOWER® products or the ore from the Vermont mine or other sources of talc?
A. No.
Q. Did you review any testimony from any of Johnson & Johnson's corporate witnesses related to the source of -- let me just ask it this way.
Did you review any testimony of anyone other than Dr. Longo and Dr. Rigler?
A. Yes, I reviewed reports only by Krekeler, Cook and Campion.
Q. And you reviewed their reports, but you haven't commented on any of those reports; is that correct?
A. There was no need to comment on those reports because they did not have -- they did not bear on my evaluation of the methodology of Longo and Rigler.
Q. Okay.
A. But I read them just in case.
Q. All right. Am I correct that you don't have an opinion one way or another as to whether or not there is asbestos in

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Vermont talc that was a source for Johnson's baby powder?
A. Can you restate that question?
Q. I didn't see anywhere in your report an affirmative opinion as to whether or not there is or is not asbestiform materials, asbestos fibers, in the talc from either Vermont or Italy or China that was the source of Johnson's baby powder.
MR. LOCKE: Objection.
THE WITNESS: No, my job in this matter was to review the methodology of Drs. Longo and Rigler.
QUESTIONS BY MR. FINCH:
Q. Did you review the testimony of -- do you know Ann Wylie, by any chance?
A. I believe I've met Ann Wylie once, maybe, but I couldn't pick her out of a crowd.
Q. Did you review her testimony that was taken in connection with these cases as part of your work here?
A. No.
Q. You have written papers with Matthew Sanchez, correct?

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A. My name appears on publications in which the author list includes Matt, yes.
Q. Have you reviewed any of Mr. Sanchez's testimony in connection with any Johnson & Johnson talc litigation?
A. No.
Q. You have published multiple papers and also a book with a gentleman by the name of Mickey Gunther, correct?
A. That's correct.
Q. Have you ever reviewed any of Dr. Gunther's testimony in asbestos litigation on behalf of any of the parties that he's worked for?
A. No.
Q. Did you review any deposition or trial testimony of any Johnson & Johnson witness in connection with your work in this case?
And by that I would include Dr. John Hopkins or any of the other employees or former employees of Johnson & Johnson.
A. No.
Q. Did you review any summaries of

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any deposition or trial testimony of anyone other than possibly Dr. Longo and Dr. Rigler?
A. No.
Q. When you were first contacted to work on behalf of Johnson & Johnson, who did you -- how did -- how were you first contacted?
Who contacted you?
A. I -- to the best of my memory, I was sitting in my Mount Holyoke office, and I got a phone call from a lawyer in Cleveland.
Q. This was a lawyer for the Tucker Ellis firm?
A. I'm not sure where he works.
Q. What was the name of the lawyer?
A. Chris Caryl, Caryl. I'm not sure how you pronounce his name.
Q. And in that conversation, what did he ask you to do?
A. He asked me if I had ever done any expert witness work and if that would interest me, and he told me a little bit about the case. I don't remember exactly

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what he said, but he asked me if I'd be interested, and I said I would think about it.
Q. And obviously you eventually said yes, correct?
A. Correct.
Q. And you ultimately put together an expert witness report that contains your opinions and conclusions in this case; is that correct?
A. Yes.
MR. FINCH: Lizzy, can I have the report?
(Dyar Exhibit 2 marked for identification.)
QUESTIONS BY MR. FINCH:
Q. Ma'am, I've marked as Darby Dyar Deposition Exhibit 2 a document entitled "Expert Report of M. Darby Dyar, Ph.D., for General Causation, Daubert Hearing."
Can you take a look at this document and tell me what it is?
A. This is my report.
Q. And it has a copy of your CV attached to the back of it as Exhibit B?

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Exhibit A, excuse me.
A. Yes.
Q. Did you, as part of your work in this case, ask to see the same samples that Dr. Longo in his laboratory analyzed, have those sent to you so you could analyze them yourself?
A. No.
Q. Why not?
A. My job here was to review the methodology employed by Drs. Longo and Rigler. It was not to do testing.
Q. Did you review any testimony of Dr. Longo other than his deposition taken in this case in February of this year?
A. No.
Q. Did you review any of Mark Rigler's testimony other than his deposition taken in connection with these cases in February of this year?
A. No.
Q. So am I correct that you have never reviewed testimony of Dr. Longo where he describes his methodology generally that his lab follows for analyzing substances to

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determine whether they have asbestos in them?
A. Other than the depositions taken this year, no.
Q. And the depositions that were taken this year was a one-day deposition taken February 5th or 6th of 2019?
A. I believe that's correct.
Q. Were you aware that Dr. Longo has testified dozens of times about -- in courtrooms with judges, both federal and state present, about the methodology he follows to analyze the presence of asbestos fibers in materials?
A. That's what he says in his -- in the beginning of his most recent deposition, yes.
Q. And you didn't ask to review any of that testimony where he describes what he does or how his lab works in detail?
A. The current deposition makes it clear that his methodology has remained constant, and so it wasn't necessary to review previous methodologies.
Q. What is your understanding of what an expert witness report like Exhibit 2

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is for?
A. It is to present the opinion of an expert witness on matters that they are asked to evaluate.
Q. Do you have the understanding that it is supposed to set forth your opinions and the bases for your opinions on various topics?
A. Yes.
MR. FINCH: Let's mark as Exhibit 3 -- and I don't have a hard copy with me because I just got it by e-mail last night -- the production materials that were sent to us at 5:50 p.m.
And could I switch to the iPad?
VIDEOGRAPHER: No problem.
MR. FINCH: And we'll send this to the court reporter electronically.
(Dyar Exhibit 3 marked for identification.)
MR. CHACHKES: We have paper copies here.
MR. FINCH: If you've got a paper copy you can hand to me, that

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would probably speed up the process a little bit.
MR. CHACHKES: We could actually have it -- so if we want one for the witness as well -- so we've got one copy. We can take a break and --
MR. FINCH: I don't want to take a break.
MR. CHACHKES: Okay.
MR. FINCH: I'll come back to it. But I'm going to ask a few questions now, and then if you can, at a break --
QUESTIONS BY MR. FINCH:
Q. Okay. Ma'am, can you see the screen here that I'm flipping?
A. No.
Q. There's a screen in front of you.
A. That's way too small.
Q. Okay.
A. I can certainly use the paper copy.
MR. CHACHKES: So I've got the

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paper copy.
MR. FINCH: All right. Counsel for Johnson & Johnson kindly provided the witness with his copy.
QUESTIONS BY MR. FINCH:
Q. But suffice it to say, did you have the understanding that some additional material was provided to us yesterday in connection with the subpoena you got?
A. Yes.
Q. Okay. What is your understanding of what was provided to us?
A. I believe it was copies of my bills and a copy of my updated CV.
Q. Okay. And also contained some --
A. Oh, and -- okay, go ahead.
Q. I've got your bills. I've got your updated CV.
What is the material, say, the last hundred pages, hundred-plus pages, of the document?
A. Those would be my spreadsheets.
Q. Okay. Are those the spreadsheets that underlie the conclusions

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and calculations that you've made and set forth in the report, Exhibit 2?
A. Yes, they are.
Q. So basically if I want to check your math, I look at the spreadsheets, right?
A. Correct.
Q. Okay. So you said you were first contacted sometime last fall by a lawyer named Christopher Caryl from the Tucker Ellis law firm about doing expert witness work for Johnson & Johnson; is that correct?
A. That is correct.
Q. And I have on the screen here, which you probably can flip to, a series of invoices beginning in November of 2018 which reflects work done in October, all the way up through a March 4th invoice which reflects work done in February of 2019.
Do you see those invoices?
A. I do see them, yes.
Q. Okay. My document isn't page numbered, but on the screen there is a contract signed by you on behalf of your company and Johnson & Johnson.

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Do you see that?
A. Yes.
Q. Okay. You started working on this project before the contract was signed.
Why is that?
A. Because I -- before this contract was signed, because I -- it took me a while to get the legal paperwork for Palouse Minerals organized and approved by Massachusetts.
Q. Okay. So you had to set up the LLC. You started doing work, you set up the LLC, and once that was set up, you had Johnson & Johnson's attorneys enter into a contract with you on behalf of LLC, correct?
A. Correct.
Q. Okay. The first invoice I have here reflects work done in October, and it has an entry for 19 hours and 18 hours, both billed at $500 an hour, for a total of 18,500.
Do you see that?
A. Yes.
Q. Okay. What is the 19 hours and what is the 18 hours?

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MR. CHACHKES: Objection.
Are you asking what's been redacted?
MR. FINCH: Well, I'm asking if -- is the redaction basically a description of the work, or is the redaction the name of a person?
MR. CHACHKES: So you can -- I'm going to object on work product grounds.
You can answer on a general high level.
THE WITNESS: Can you restate that question, please?
QUESTIONS BY MR. FINCH:
Q. Yeah.
There's a breakdown between 19 and 18 hours. Is all the work in all these invoices performed by you?
A. Absolutely, yes.
Q. Okay. So there's nobody else that's done any work on this expert witness report or your analysis of Dr. Longo and Dr. Rigler's reports, correct?
A. No.

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Q. Did you confer with anyone in connection with your review of Dr. Longo's -- and rather than saying Longo and Rigler again and again and again, I'm just going to say Longo.
Did you confer with anyone in connection with your review of Dr. Longo's reports or your writing of your report?
MR. CHACHKES: Objection.
THE WITNESS: Yes.
QUESTIONS BY MR. FINCH:
Q. Who did you confer with?
A. Counsel.
Q. That would be lawyers for Johnson & Johnson?
A. Yes.
Q. Did you share drafts with them of your report?
A. Yes.
Q. Did they provide comments on the drafting?
A. Yes.
Q. Did you consider their suggestions in writing your report?
MR. CHACHKES: So I'm going to

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object on work product grounds. The communications with Professor Dyar are going to be privileged, so I'm going to ask the witness not to respond to this line of questioning.
MR. FINCH: So noted.
QUESTIONS BY MR. FINCH:
Q. Did any lawyers for Johnson & Johnson suggest areas of inquiry for you as part of your analysis of Dr. Longo's work?
MR. CHACHKES: So same objection.
Please don't respond.
QUESTIONS BY MR. FINCH:
Q. Did any lawyers for Johnson & Johnson provide you with any of the pictures that appear in your report?
A. Some of the images in my report come from the Longo, Rigler reports. So to the extent that I received the Longo and Rigler reports from counsel, then, yes, some of the images came from there.
Q. Did you review all of the, for lack of a better word, backup material for all of the Longo and Rigler reports?

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A. I looked at every single page.
Q. Did you look at every single photograph or photomicrograph on every single page of Dr. Rigler and Dr. Longo's backup materials to their reports?
A. Yes.
Q. Did you confer with anyone else on either your analysis of Dr. Longo and Rigler's work or your report, other than Johnson & Johnson's lawyers?
A. Yes.
Q. Who did you confer with?
A. Dr. Mickey Gunther.
Q. Who else?
A. No one else.
Q. Did Dr. Gunther provide any written comments or suggestions to you in your work analysis -- your work in this case?
MR. CHACHKES: So again, I'm going to object on work product grounds. Dr. Gunther is a consultant for J&J, so I'm going to ask the witness not to respond to this line.
MR. FINCH: Well, we disagree with that, but we'll take it up at the

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appropriate time.
QUESTIONS BY MR. FINCH:
Q. Did you review Dr. Campion's report and publications in connection with your work in this case?
A. I did look at them, yes.
Q. Did you come to any conclusions about them?
MR. CHACHKES: So I'm going to object to this on work product grounds. To the extent there were any communications, it was not with respect to this report.
QUESTIONS BY MR. FINCH:
Q. You don't intend to testify about any conclusions related to Dr. Campion's report?
A. My purpose here was to review only the Longo and Rigler reports.
Q. In November of 2018, you sent an invoice for 37 hours of work -- for work done in October of 2018.
What were you reviewing or doing during that 37 hours given that Dr. Longo didn't issue his first report in

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the MDL until the middle of November?
A. I was reviewing prior documents, prior reports, of Dr. Longo.
Q. You mean his reports done in connection with state court asbestos litigation from 2018, earlier in 2018 and partially in 2017?
A. Let's have a look at the list of documents that I included in my report.
Q. You're looking at Exhibit Number 3 -- 2, Exhibit Number 2.
A. So the first document was produced in March -- on March 11, 2018.
Q. Uh-huh.
A. Another document was produced on September 6th of 2018, and another one was produced in September of 2017. So those documents were available to me immediately. And then when the October 2018 document became available, it was given to me.
Q. So your November invoice was for $18,500; December, 30,000; January, 25,500; February invoice for January work, 35,000; and then your March invoice for February work was 63,000. Is that correct?

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A. That's correct.
Q. Okay. So in total you've billed over $150,000 to this project so far, at least as of the end of February 2019?
A. I haven't done the math, but that seems about right.
Q. How much time have you spent in March of 2019 working on this project?
A. I don't really know, but not much. I wouldn't like to speculate without checking my records.
Q. More than 20 hours?
A. Yes.
Q. More than 50 hours?
A. Probably no.
Q. How about in April?
I know it's only the 2nd day of April, but did you spend any time yesterday?
A. Yes.
Q. What did you do yesterday as part of your work for Johnson & Johnson in this case?
MR. CHACHKES: So again, I'm going to object on work product grounds, but you can answer on a very

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high level.
THE WITNESS: I prepared for this deposition.
QUESTIONS BY MR. FINCH:
Q. And what did you do to prepare for this deposition?
MR. CHACHKES: Again, I'm going to object on work product grounds and maybe counsel the witness not to answer.
If you have any specific questions that don't threaten the work product protections, then you can ask those.
MR. FINCH: I'll leave the question as it is.
MR. CHACHKES: Okay. So please don't answer.
QUESTIONS BY MR. FINCH:
Q. On the invoices where it says "redacted" in several places, can you tell me generally what kind of information was redacted?
Is it information relating to what you were doing, or is it information

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like Social Security numbers or something like that?
A. It's information related to what I was doing.
Q. Okay. So it describes the tasks that you were performing in connection with your expert witness work in this case?
A. Correct.
MR. FINCH: All right. We would make a request for an unredacted version of the invoices.
MR. CHACHKES: We'll take it under advisement.
MS. SHARKO: Any requests, please put in writing.
MR. FINCH: Okay. This is writing, since someone's writing it down, but we will do it in a letter.
MS. SHARKO: Okay. And keep in mind that we will then reciprocate.
QUESTIONS BY MR. FINCH:
Q. Let's just get some terms on the record.
What does EDS, EDXA stand for?
A. Energy-dispersive spectrometry,

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or spectroscopy, depending on how you define it, and then other people call it energy-dispersive X-ray analysis. They're general terms for the same thing.
Q. And am I correct that that is a test for elemental chemistry?
A. It's a qualitative test for elemental chemistry.
Q. Qualitative, q-u-a-l-i-t-a-t-a-v-e {sic}?
A. Correct.
Q. And that is an analysis performed by a transmission electron microscope, correct?
A. Yes.
Q. Explain what is SAED.
A. SAED refers to a kind of electron diffraction done on a TEM in which the electrons are passed through the sample and they are diffracted, resulting in a pattern.
Q. And am I correct that when a sample is analyzed under SAED, the material is placed, for lack of a better word, on the plate of the transmission electron

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microscope, and it is possible for the analyst to rotate it in various dimensions and directions?
A. Yes, that is correct, and as described in the quotation on page 31 of my report.
Q. And so -- which quotation are you referring to?
A. The quotation from ISO 2262-1 {sic} on page 65 which describes the process by which you align a sample for an SAED pattern.
Q. Okay. And am I correct that that is something that the analyst, when looking at the substance or the structure through the TEM, is rotating the material in realtime and deciding when to make an image of that?
A. Correct.
Q. And is it correct that an analyst, in reviewing the structure or substance in realtime, can decide to take an image of the selected area of diffraction pattern whenever, in his or her judgment, he finds something worth capturing?

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MR. CHACHKES: Objection.
THE WITNESS: That would be a standard operating procedure, yes.
QUESTIONS BY MR. FINCH:
Q. So a standard operating procedure would be the analyst takes the substance or material and has the ability to rotate it in three dimensions and analyze the crystal structure of the material under the TEM, correct?
A. It's not a full three dimensions, but it's basically a plane that has the ability to be tilted by a small number of degrees in various directions.
Q. Okay. And in the process of doing that, the analyst can spend as much or as little time as it takes him or her to look at the structure or material in the various dimensions and take a picture, for lack of a better word, of the diffraction pattern at whatever points in time he or she thinks are important, correct?
A. Correct.
Q. And it's -- it is in some sense the judgment of the analysts at what point in

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time he or she takes the picture of the selected area of diffraction pattern, correct?
A. Yes.
Q. You have degrees in geology and art history; is that correct?
A. Correct.
Q. You have a Ph.D. in geology?
A. My Ph.D. is actually in geochemistry.
Q. In geochemistry.
And how did you first get interested in geology?
A. I don't actually recall. I think when I was 2 years old, my mother reports that I picked up rocks instead of Easter eggs on an egg hunt. That was the first indication that maybe geology was in my future.
Q. You graduated with a bachelor's of art in geology and art history from Wellesley College, correct?
A. As it says in my résumé, when I -- at the time I graduated, my BA was in geology, and I finished the course

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requirements for the art history degree while I was enrolled at MIT subsequent to my graduation from Wellesley.
Q. And you got your Ph.D. in geochemistry from MIT, correct?
A. Correct.
Q. You're not an epidemiologist, correct?
A. No.
Q. You're not a medical doctor?
A. No.
Q. You don't hold yourself out as an expert on the biological activity of substances in the human body; is that correct?
A. No.
Q. You're not a cell biologist?
A. I work with a microbiologist and I have written papers on microbiology, but I don't consider myself a cell biologist, no.
Q. Do you hold yourself out as an expert in analyzing whether or not and how fibers and structures can cause genetic errors which lead to cancer or other

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diseases?
A. No.
Q. You're not a toxicologist?
A. No.
Q. Have you ever performed an animal study in the sense of either having an animal ingest or inhale or otherwise come into contact with a substance to determine whether that substance has hazardous effects?
A. No.
Q. I take it you do not have an expert opinion as to whether any of the materials found in Johnson & Johnson's talc or Johnson & Johnson's baby powder are carcinogenic?
A. I have no opinion on that.
Q. You have no expert opinion regarding whether any amphiboles found in talc from New York, the Gouverneur talc mine, are carcinogenic; is that correct?
MR. LOCKE: Objection.
THE WITNESS: I have no opinion on that.
QUESTIONS BY MR. FINCH:
Q. Do you have any opinion about

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whether the amphiboles found in Libby vermiculite are carcinogenic?
A. I have no opinion on that.
Q. You have no expert opinion on that?
A. No.
Q. Are you familiar with the fact that there has been an epidemic of mesothelioma in and around Libby, Montana?
MR. FROST: Objection.
MR. LOCKE: Objection.
THE WITNESS: Vaguely.
QUESTIONS BY MR. FINCH:
Q. How did you come to that understanding?
MR. FROST: Objection.
THE WITNESS: I read it in a newspaper maybe?
QUESTIONS BY MR. FINCH:
Q. When was the first time you met Mickey Gunther?
A. In the summer of 1996, I met Mickey at a teaching mineralogy workshop at Smith College.
Q. Were you on the faculty of that

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workshop, or was he on the faculty of that workshop? How did you come in contact?
A. I was driving a van on the field trip, and Mickey got in and sat next to me.
Q. And since that time, you have collaborated on both a textbook and about, what, 30 papers, something like that?
A. I don't keep count of the papers, but they're all as listed in my CV.
Q. Could you identify for me your peer-review publications which address the subject of how to determine if a material is asbestos in the environment?
MR. CHACHKES: Objection.
THE WITNESS: I would have to spend some time going through the list to see if there are any that satisfy those criteria. I don't recall.
QUESTIONS BY MR. FINCH:
Q. Can you think of any off the top of your head right now?
A. No.
Q. Have you ever published a peer-review publication regarding how to

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determine if there is asbestos in a product?
A. Not that I recall.
Q. Have you published any peer-review articles regarding the use of -- I'm just going to use the shorthand term -- EDS, EDXA, to identify asbestos in materials?
A. Not that I recall.
Q. Have you ever authored a peer-review publication concerning the use of selected area diffraction -- selected area electron diffraction, SAED, to identify asbestos in materials?
A. Not that I recall.
Q. Have you ever published a peer-review paper regarding the use of polarized light microscopy, PLM, to distinguish between asbestos in talc in materials?
A. Not that I recall.
Q. Have you ever been asked by the United States Environmental Protection Agency to draft standards relating to the identification of asbestos in a material?
A. No.
Q. Have you or laboratories -- let

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me back up.
Have you ever been in charge of a laboratory where the laboratory regularly tested materials to determine if they contained asbestos?
A. No.
Q. Have you analyzed over 300 samples of material -- 300,000 samples of materials over the course of your career to detect whether or not asbestos was present in them?
A. No.
Q. Have you ever been recognized by a court as an expert witness on the subject of examining material to determine whether it contained asbestos?
A. No.
Q. Have you ever served as an expert consultant for the City of New York, the State of New York, the State of Utah or any other governmental entity on the subject of examining material to determine whether it contained asbestos?
A. No.
Q. Have you ever been the primary

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author of an American Society Testing and Materials method for the analysis of asbestos fibers and bundles in settled dust?
A. No.
Q. Have you ever been the primary author of any ASTM memorandum?
A. No.
Q. You cite to several different ISO memorandums relating to the identification of asbestos in either bulk samples or in the air or in talc, correct?
A. Correct.
Q. Have you ever been the author or a contributor to an ISO memorandum relating to the identification of asbestos in bulk samples?
A. No.
Q. Have you ever been the author or contributor to an ISO memorandum relating to the identification of asbestos in the air?
A. No.
Q. Have you ever been the author or contributor to an ISO memorandum relating to the identification of asbestos in talc?
A. No.

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Q. Have you ever tested a sample of talc to determine whether or not it contained asbestos?
A. No.
Q. Have you ever published anything in any peer-reviewed journal about testing talc to determine if it contains asbestos?
A. No.
Q. What -- and I'm going to butcher this word repeatedly because it's just one of those words I just cannot say. But what microscopy-based spectroscopic methods have you used over the course of your career?
A. Oh, Mössbauer spectroscopy, electron spectroscopy of various kinds, TEM, SEM, electron probe microanalysis, X-ray diffraction, X-ray fluorescence, proton-induced gamma emission, laser-induced breakdown spectroscopy, Raman spectroscopy. Those are some of them.
Q. Do you oversee a lab currently that has electron microscopes?
A. No. The lab that contains an

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SEM and TEM at Mount Holyoke is overseen by the director of the science center.
Q. Do you have access to that lab?
A. Yes.
Q. Can you list the various types of electron microscopes you have used to analyze materials over the years?
A. You want to clarify what you mean by "type"?
Q. Well, the manufacturer, the model.
A. No, I don't pay attention to that. I'd have to go back and look at the papers.
Q. Are you aware that the National Bureau of Standards publishes asbestos standards?
A. Yes.
Q. Have you analyzed the National Bureau of Standards asbes -- standard asbestos samples in any laboratory where you've worked?
A. I can't recall. I've analyzed hundreds of thousands of samples in my career, so it's difficult to recall if one or

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two of them were -- happen to be those standards. I don't recall.
Q. How many -- what is the primary laboratory that you've worked with over the past ten years?
Is it the Mount Holyoke?
A. My research takes place at many different institutions. I work with the synchrotron at the Advanced Photo Source, Photon Source, in Chicago. I work with scientists at Los Alamos National Laboratory, and I work with scientists at the University of Massachusetts in Amherst where I am on the graduate faculty.
My own laboratory at Mount Holyoke also includes many different kinds of spectrometers.
Q. And your own laboratory at Mount Holyoke has a SEM and a TEM now?
A. No. As I stated, Mount Holyoke has an analytical facility for TEM and SEM, which is under the direction of the director of science center.
Q. And the science center is affiliated with what entity?

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A. All of the science departments at the college.
Q. Okay. Do you know what NVLAP NIST accredited means?
A. I know what NIST stands for.
Q. Do you know if any of the laboratories you've worked in are NVLAP NIST accredited?
A. So academic institutions are accredited by completely differently organizations than the ones that are used for business entities.
And, yes, Mount Holyoke does have an accreditation.
Q. Have you ever calibrated an electron microscope for electron diffraction?
A. Probably 30 years ago, yes.
Q. You haven't done it in the past 30 years?
A. Our equipment is already kept well-calibrated. We have a full-time laboratory manager who takes care of the EMs.
Q. Have any of the labs that you have worked with or for been in the NVLAP NIST program for the identification of

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asbestos?
A. I have no knowledge of that.
Q. How much time do you spend on a daily basis analyzing materials to determine whether or not they contain asbestos fibers?
A. Zero.
Q. How much time do you spend on a weekly basis analyzing materials to determine whether or not they contain asbestos?
A. Zero.
Q. How much time do you spend on a yearly basis analyzing materials to determine whether or not they contain asbestos?
A. Zero.
Q. What are the steps for identifying and assessing whether a sample of a material contains asbestos?
A. Well, let's go back to my report where that's articulated quite clearly.
So, for example, my report talks about the Yamate -- the Yamate document from the EPA, it talks about the ISO 22262 document, and it also talks about PLM methods explained and described in the Su documents.

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So there are many different ways of answering that question.
Q. Okay. Do you find the methodology set forth in ISO 22262-1 and 22262-2 to be reliable standards that a scientist should follow for analyzing whether or not a sample of material contains asbestos?
A. It would depend on -- the answer to that question would depend on the level of asbestos.
So you want to be more specific?
Q. Any level.
A. Want to -- would you please restate the question?
Q. Yes.
Do you --
MR. FINCH: Could you read back the question, madam court reporter?
No? Okay. I'll see if I can...
QUESTIONS BY MR. FINCH:
Q. Do you find the methodology set forth in ISO standards 22262-1 and 22262-2 to

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be reliable standards that a scientist should follow for analyzing whether or not a sample of a material contains asbestos?
A. I would say that in the case of determination of bulk asbestos, the methods in those documents are robust.
Q. What about for determining whether or not there is asbestos in talc?
A. So those -- so Document 1, for example, which you mentioned, explicitly says it's for measurements of bulk samples, and Document Number 3, which is the one relating to X-ray diffraction, explicitly says that XRD has some limitations. And so ISO document 22262-2 is the only one that is really relevant to looking at small amounts of asbestos.
Q. Okay. Do you regard the standard set forth in ISO 22262-2 to be reliable for a scientific -- a scientist to follow to analyze whether or not there are small amounts of asbestos in talc?
A. You know, my goal in this report was to evaluate whether the methodology of Drs. Longo and Rigler was

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valid. It was not to evaluate whether the government documents on this topic are appropriate. So I have not thought about that.
Q. Okay. So you don't -- you don't criticize the standards in -- or the methodology set forth in ISO 22262-2; is that correct?
A. It's a government document. I haven't been asked to think about criticizing it, and so I haven't thought about it.
MR. CHACHKES: And we've been going about an hour. If you reach a natural pausing point, we'll take maybe a little break.
MR. FINCH: Okay. Let me go about another five minutes.
MR. CHACHKES: Sure.
QUESTIONS BY MR. FINCH:
Q. When was the last sample that you analyzed that contained asbestos?
A. What do you mean by "analyzed"?
Q. Analyzed using any of the tools that a scientist could use to determine whether a substance or material contains

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asbestos, either a PLM or TEM or any other way.
A. I have in the past year undertaken Mössbauer spectroscopy on asbestos samples to determine their ferrous ratios, but that is unrelated to the question of determining whether asbestos is present or not because I already knew that SAED samples were asbestos.
Q. Okay. Do you recall when is the last time you analyzed a sample where you didn't know whether or not asbestos was present to determine if, in fact, it contained asbestos?
A. Never.
Q. Never done that?
A. No.
Q. You have -- I think I counted this up right; maybe I missed one.
You have three publications that deal with materials found in the vermiculite from Libby, Montana; is that right?
A. I contributed Mössbauer analyses to three papers, yes. I did not

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have anything to do with writing the papers.
Q. Okay. Your name appears on those papers, right?
A. Correct. Because as is appropriate in science, I contributed data to the endeavor and, therefore, was included as a coauthor.
Q. And Mickey Gunther is the lead author on several -- on those papers, or is at least an author on each of those papers?
A. I don't know. I'd have to look, but I would presume so.
Q. So am I correct that you did not analyze any of the material that came from the vermiculite from Libby, Montana, to determine whether or not it had asbestos in it?
A. Correct. I only analyzed things to determine the redux ratios.
Q. Okay. You mentioned something called the Mössbauer spectrum?
A. Correct.
Q. All right. Could you describe what that is?
A. A Mössbauer spectrometer is

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used to evaluate how much oxygen was available at the time a mineral crystalized, so in particular it's used to measure the valent state of iron, whether it is oxidized iron, which would be ferric iron, or reduced iron, which would be ferrous iron. That is one of my specialties.
Q. So one of your specialties is using the Mössbauer analysis to determine, for lack of a better word, the iron content of something that might have asbestos in it?
A. One of my specialties is to use Mössbauer spectroscopy to determine the iron redux ratio of minerals among the 5,500 known minerals. That's one of the specialties, yes.
MR. FINCH: All right. This is a good time to take a break.
VIDEOGRAPHER: The time is 10:05 a.m. Going off the record.
(Off the record at 10:05 a.m.)
VIDEOGRAPHER: We are back on the record. The time is 10:21 a.m.
(Dyar Exhibits 4, 5, 6 and 7 marked for identification.

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QUESTIONS BY MR. FINCH:
Q. We're back on the record after a short break.
Do you prefer to be called Dr. Darby Dyar or Ms. Darby Dyar?
A. How about Professor Dyar.
Q. Okay. Professor Dyar.
I've marked and put in front of both you and your lawyer copies of Darby Dyar Exhibit 4, 5, 6 and 7.
A. Yes.
Q. And can you tell me what each of those is?
A. So these documents are the air quality testing International standard ISO 22262-1 and 2, and ISO 13794, as well as the Yamate report from the EPA dated July 1984.
Q. Okay.
What is the International Standard Organization?
A. I don't actually know.
Q. When is the first time you reviewed or saw ISO 22262-1? This is Dyar 4.
A. When I saw it referenced in Dr. Longo's report.

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Q. Okay. So you had never previously had occasion in your career to rely on the International standard for sampling and qualitative determination of asbestos in commercial bulk materials; is that correct?
A. In my research I use and have used these techniques for almost 40 years, but I have not yet brought them to bear on the study of asbestos as an impurity in talcum powder.
Q. Okay. So you never had the -- prior to your engagement by Johnson & Johnson in this case, you never reviewed the methodology set forth in ISO 22262-1; is that correct?
MR. LOCKE: Objection.
THE WITNESS: Can you state the question again?
QUESTIONS BY MR. FINCH:
Q. Yeah.
Prior to being retained by Johnson & Johnson as a potential expert in these ovarian cancer cases, you never had occasion to review ISO 22262-1 and the

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methodology that it lays out for determination of asbestos in commercial bulk materials; is that correct?
MR. LOCKE: Objection.
THE WITNESS: I have never reviewed this specific document, but I have reviewed countless times the use of polarized light microscopy in the detection and analysis of minerals. It's something I routinely teach and it's something that I routinely use in my research, but, again, not for the purpose of detection of asbestos specifically.
QUESTIONS BY MR. FINCH:
Q. Am I correct -- well, let me just ask it.
Have you ever reviewed ISO Standard 22262-2 prior to your retention by Johnson & Johnson in these cases?
A. No. There was no need.
MR. FINCH: Move to strike that "there was no need."
QUESTIONS BY MR. FINCH:
Q. Would you agree with me that

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ISO 22262-1 and ISO 22262-2 lay out the methodology -- a methodology for a scientist to follow in order to determine whether or not for ISO 22262-1, whether or not there's asbestos in commercial bulk materials, and ISO 22262-2, whether there is asbestos in talc?
A. These two documents do describe protocols for analyzing asbestos, yes.
Q. And if an analyst follows those protocols, would you criticize him or her for doing so?
A. So if we go back to my report, we'll see numerous places where I talk about the proper use of these tools for the analysis of asbestos in amphibole.
Q. But you're not criticizing the methodology set forth in ISO 22262-1 or 22262-2; is that correct?
A. Do you want to be more specific by what you mean about methodology?
Q. Yeah.
The steps that they -- the ISO -- let's say, ISO 222 -- you agree that ISO 22262-1 and ISO 22262-2 lay out the steps

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that a scientist should follow and the tools that the scientist should use to determine whether or not there is asbestos in either a bulk commercial material or in talc?
A. I would say that they lay out some of these steps that should be used, and if done correctly, they would be useful. But in my report, I talk about the possible downside of many of these methods.
So, for example, polarized light microscopy, if done correctly, can be useful in identifying minerals, but for the possible -- and for the analysis of possible impurities of -- in talcum powder, there are many minerals that would have the same PLM characteristics, so the results might well be inconclusive.
Q. Am I correct that ISO 22262-2 lays out a methodology and different tools for a scientist to use to determine whether or not there is asbestos in talc? Correct?
A. So 22262, as it states --
Q. Dash 2.
A. Dash 2 -- talks about the use of gravimetry and microscopic methods, and it

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is designed to be used for quantitative analysis of materials that are described on the first page of that document's narrative.
Q. Which includes talc, correct?
A. Yes, mineral products such as wollastonite, dolomite, calcite, talc or vermiculite.
Q. And ISO 22262-2, in some instances, refers back to ISO 22262-1 for how to use the tools or analyze the data that one obtains from using the tools to determine whether what you were analyzing is asbestos or not, correct?
A. Yes, these documents reference one another and also other preexisting documents.
Q. Okay. Are you familiar with what I've marked as Dyar 6, ISO -- before I get to Dyar 6, am I correct that the first time you reviewed ISO 22262-1 or 22262-2 was in connection with your work as a paid expert work by Johnson & Johnson?
A. Yes. As a research scientist, I have no need of anyone to tell me what -- how to use these tools in my own research

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because I've been trained to use these tools over the course of my 40-year career, so there was no need to consult a standard of this sort.
Q. Have you ever reviewed or seen ISO 13794 prior to your engagement by Johnson & Johnson in these cases?
A. No, because I had no need for instruction in how to use a TEM or how to do point counting. I already know how to do that in my research as affirmed by my peer-reviewed publications.
Q. Are you familiar with Dyar Exhibit 7?
A. Yes.
Q. What is Dyar Exhibit 7?
A. Dyar Exhibit 7 is a methodology from George Yamate, written as an EPA report in 1984.
Q. And what is the title of this document?
A. The title of this document is "Methodology for the Measurement of Airborne Asbestos By Electron Microscopy."
Q. And this was a contracted

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report for the Environmental Protection Agency?
A. That's my understanding, yes.
Q. Were you aware that Mr. Yamate at one point worked for Bill Longo?
MR. CHACHKES: Objection.
THE WITNESS: I have no knowledge of that.
QUESTIONS BY MR. FINCH:
Q. When is the first time that you reviewed -- or can we just agree that we're going to call Dyar 7 the Yamate report?
A. Sure.
Q. When's the first time you reviewed the Yamate report?
A. For this particular case.
Q. You never reviewed it before this?
A. No, it wasn't necessary because I already know how to do electron microscopy, as evidenced by my many peer-reviewed publications that use the technique.
Q. And would you agree with me that this Yamate report, Dyar 7, lays out three different methodologies called level 1

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analysis, level 2 analysis and level 3 analysis for determining whether or not there is asbestos in some kind of substance?
A. Yes, that's what it says.
Q. Do you have any opinion about whether or not following these protocol would be a reliable thing for a scientist to do in analyzing whether there's asbestos in a substance?
A. I have an opinion on the fact that Dr. Longo did not follow this guideline. He did not do any of the level 3 protocols expressed in this, including reporting two different zone axis SAED patterns.
Q. Am I correct you have not reviewed any Johnson & Johnson internal documents relating to testing it did of either Johnson's baby powder or talc?
A. Correct, because my goal in this investigation was to evaluate the methodology of Drs. Longo and Rigler.
Q. My colleague, Mr. Geier, pointed out that in the prior question I asked you whether or not you have an opinion about whether or not following the Yamate

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protocol would be a reliable thing for a scientist to do in analyzing whether there's asbestos in a substance.

And your answer was, "I have an opinion on the fact that Dr. Longo did not follow this guideline. He did not do any of the level 3 protocols expressed in this, including reporting two different zone axes SAED patterns."

My question is a little bit different. My question is, if a scientist follows the Yamate level 3 protocol for the number of samples or percentage of samples it says to apply that protocol to, would you have any criticism of the protocol itself as a way for detecting asbestos in talc -- in talc or any other substance?

A. Yes, I would have criticisms because SAED only identifies which mineral species it is. It does not say anything about the morphology of the particle.

Q. Would you agree with me that there are different tests to determine whether or not there is asbestos in a sample or substance?

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A. Certainly there are different tests that determine the presence of asbestos.

Q. Okay. One of them you mentioned was SAED.

That's to determine the crystalline structure, correct?

MR. CHACHKES: Objection.

THE WITNESS: SAED can be used to determine the mineral species that is present in the sample. It's used in a very wide variety of applications. It cannot prove that something is asbestos.

QUESTIONS BY MR. FINCH:

Q. It cannot prove by itself that something's asbestos, correct?

A. Correct.

Q. When used in conjunction with other tools such as PLM or TEM, EDS, EDXA, isn't it true that you can come to a conclusion whether or not a given material is asbestos?

MR. FROST: Objection. Form.

THE WITNESS: So SAED is used to identify the mineral species that is present. EDS is used to identify the chemical composition of what is present. Neither of those techniques can tell you anything about the morphology of the particle that is present and, therefore, they are not -- those two techniques together could not tell you if asbestos was present.

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QUESTIONS BY MR. FINCH:

Q. What technique could -- isn't it true that the morphology of the particle is examining under a microscope and determining things like the shape and size and aspect ratio?

A. True.

So if SAED, in two different zone axis determinations, were combined with EDS analyses done properly, as -- as expressed in my report, along with a survey of the population of particle morphologies present was undertaken, if all of those things were true, then it would be possible to identify something as asbestos.

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Q. A survey of population of a particle, what techniques would you use to do that?

A. So in my report, if we go to page -- let's see. It's the section beginning on page 52. So it talks here about the possibility of using a population of particles and analyzing their size to determine whether something is asbestos.

That's -- the word "population" is also used in the R-93 document that I reviewed, and populations are also referred to in the ISO documents, although I can't, without further time, tell you exactly which one.

So in these -- in many of these documents, they do refer to populations of morphologies rather than individual ones.

Q. Are you aware that Mickey Gunther has served as an expert witness for multiple defendants in asbestos litigation over the years?

MR. FROST: Objection. Form.

THE WITNESS: I'm aware that Mickey has what he calls his lawyer

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work, yes.
QUESTIONS BY MR. FINCH:
Q. He's testified at the request of W.R. Grace, for example, in cases involving its asbestos-containing vermiculite?
MR. CHACHKES: Objection.
MR. FROST: Objection. Form.
THE WITNESS: I'm not aware of exactly what Mickey does in his lawyer work.
QUESTIONS BY MR. FINCH:
Q. Are you aware that he always works for defendants in asbestos litigation and has never worked for a victim in asbestos litigation?
MR. CHACHKES: Objection.
MR. FROST: Objection.
THE WITNESS: I am not aware of what Mickey does in his lawyer work.
QUESTIONS BY MR. FINCH:
Q. Have you ever asked him what he does in his lawyer work, as you call it?
A. No.
Q. When you submit a paper to a

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peer-review journal, isn't it correct that oftentimes the authors are asked if they have any potential conflicts of interest that may bias or affect their views of the material in which they publish?
A. That's something that's started happening in the last few years, yes.
Q. And why -- in your understanding, why has that started happening in the past few years?
MR. LOCKE: Objection.
THE WITNESS: I never thought about it.
QUESTIONS BY MR. FINCH:
Q. Do you think it has anything to do with the fact that the readers of the paper are entitled to know whether the authors of the paper have any financial interest in the subject matter on which they are writing about?
A. I've never thought about it. I don't know.
Q. Do you think it's important to know whether or not a scientist has a financial interest in the work that he or she

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is doing to assess the credibility of that work?
A. I don't really have an opinion on that. I've never thought about it, to be honest.
Q. So it was not important to you in your collaborations with Mickey Gunther to ever ask him whether or not he has only and exclusively worked at the request of asbestos defendants in asbestos litigation?
MR. FROST: Objection.
QUESTIONS BY MR. FINCH:
Q. It never crossed your mind to ask him that question?
MR. CHACHKES: Objection.
THE WITNESS: It never crossed my mind to ask him that question.
QUESTIONS BY MR. FINCH:
Q. I asked if you reviewed any internal Johnson & Johnson documents relating to the testing of the talc from its mines or in its finished products, and I believe your answer was, no, you never reviewed any of those documents; is that correct?
A. No, sir.

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Q. Have you ever reviewed any documents relating to anyone else's testing of the talc in Johnson & Johnson's mines or the finished product, other than Longo and Rigler?
A. No, although I did recall over the break that I reviewed some additional reports of Drs. Longo and Rigler that didn't have any numbers on them. So I reviewed them briefly and then set them aside, so those are cited in my report.
But in terms of your current question, no other reports.
Q. Okay. So the only people who have tested Johnson & Johnson baby powder or samples of talc from the mines where the talc came from for the baby powder, the only people that you reviewed the work of are Longo and Rigler; is that correct?
MR. FROST: Objection.
THE WITNESS: I was hired to review the methodology of Longo and Rigler, so that's what I did, yes.
QUESTIONS BY MR. FINCH:
Q. Did you think it was at all

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important in analyzing the work of Longo and Rigler to compare their results and conclusions to what other scientists may have found when they've analyzed the same material -- or material from the same places?

MR. FROST: Objection.

THE WITNESS: No, it was not important because I am very familiar with the methodology that they use. And there was really no need to look and see what other people's work said because that had nothing to do with my review of the methodology.

QUESTIONS BY MR. FINCH:

Q. What is your definition of asbestos?

A. My definition of asbestos is given in my report. If we can turn to page -- let's see, page 10. Asbestos is defined as one of six particular minerals exhibiting the characteristics of an asbestiform habit, meaning that they can be separated into flexible fibers with high tensile strength.

And, of course, those six

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minerals are the ones given in the table and in other places in the report, anthophyllite, chrysotile, grunerite, tremolite, actinolite and riebeckite.

Q. What is -- in your view qualify a fiber as having the morphology that is consistent with an asbestos fiber?

A. So again, my definition of a fiber is given in the numerous literature citations on page 10 and 11, which consistently define fibers as being strong and flexible and having high tensile strength, including those in the ISO 22262, which define asbestiform in an identical way as a specific type of mineral fibrosity in which the fibers and fibrils possess high tensile strength and flexibility.

Q. Is it possible to measure the tensile strength of a fiber that's 10 microns long?

A. It is possible to constrain it with a probe, yes.

Q. How would you do that?

A. You would poke the fiber and see if it could bend.

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Q. Have you ever done that?

A. I have certainly looked at the tensile strength of mineral fibers. Not with a TEM, however.

Q. How would you measure the flexibility -- is there any -- is there any peer-reviewed literature that you would rely on or that you could cite me to that describes how you would measure the tensile strength of a fiber that is 10 microns long or less?

A. I did not consider that because that was not a method that was used by Drs. Longo and Rigler. Given sufficient time to research that topic, I'd be happy to give you an answer.

Q. As you sit here today, you can't think of any literature that lays out a methodology to test the tensile strength of a fiber that is 10 microns or less?

MR. FROST: Objection.

THE WITNESS: I would have to do background research to answer that question.

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QUESTIONS BY MR. FINCH:

Q. Have you ever mentioned -- ever measured the tensile strength of asbestos?

A. Not personally, no.

Q. What is the unit of measurement that that -- that one would use to measure the tensile strength of asbestos?

A. I don't know, and I did not consider that because a measurement of tensile strength was not part of the methodology of Drs. Longo and Rigler and, therefore, it wasn't considered by me in preparing this report.

Q. Do you know what a pascal joule is?

A. Yes.

Q. What is it?

A. It's a unit of force.

Q. It's a unit of force that is one way to measure -- it's a measurement that you can calculate or determine the tensile strength of a material, correct?

A. I'd have to research that to make sure I -- I agree with you. I have no knowledge of the exact methodology for

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measuring tensile strength but could easily understand that with a brief survey of the literature.
Q. Pounds per square inch is another way to measure tensile strength?
A. Certainly.
Q. What dimensions does a particle need to have in order for it to be potentially characterized as an asbestos fiber?
MR. FROST: Objection.
THE WITNESS: So the answer to that question refers -- or depends on which guidelines you're looking at.
QUESTIONS BY MR. FINCH:
Q. In your view. In your opinion.
A. I have no personal opinion in this matter. I just know what the different documents can tell you.
Q. So you have no opinion as to what aspect ratio must be present in order for something to be characterized as having morphology that is consistent with asbestos?
MR. LOCKE: Objection. Misstates testimony.

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MR. FROST: Objection.
MR. CHACHKES: Objection.
THE WITNESS: My assessment of the literature suggests that aspect ratio is best understood in the context of a population, and the papers by Ann Wylie and others that I reference in my report talk about amphibole populations.
And so my personal opinion is that analysis of populations is the optimal way to understand asbestos, but that is -- that is the preliminary opinion, and I'd want to think about it and do some research on it.
My personal opinion did not come up in this particular report.
QUESTIONS BY MR. FINCH:
Q. In order for a structure to meet your definition of asbestos, what does the EDS or EDXA chemical signature have to be?
MR. FROST: Objection.
THE WITNESS: You said EDS and EDXA chemical signature have to be?

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QUESTIONS BY MR. FINCH:
Q. Yes.
A. So as I said in my report, EDS and EDXA do not let -- do not have sufficient quantitative accuracy to allow discrimination between potentially asbestiform and non-asbestiform mineral species, many of which have very similar compositions, as given in Table 1 in my report.
Q. Do you agree with me that information from an EDS, EDXA chemical signature can be useful to determine whether or not a given structure is asbestos or not if used in connection with other tools?
MR. FROST: Objection.
THE WITNESS: I believe that EDS can be used to determine the presence or absence of specific elements, but it cannot be used to make quantitative judgments on the ratios of the concentrations of those elements.
That's not only my opinion but the opinion of Newbury and Ritchie and the National Institute of Standards

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and Technology and numerous other scientists.
QUESTIONS BY MR. FINCH:
Q. Do you agree that SAED is a useful tool to determine whether or not a particle or structure has a crystalline structure that when used in conjunction with other tools allows you to determine whether or not it's asbestos or not?
A. SAED is a tool that allows you to determine what the crystal structure of the particle is. You would need other information to determine whether the particle was asbestos.
Q. How would you measure the flexibility of an asbestos fiber that is 10 microns or less in length?
MR. FROST: Objection. Asked and answered.
MR. FINCH: No, I asked about tensile strength.
THE WITNESS: So I would imagine that you would use a probe, but I would have to do some more research. And I can certainly do

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that, but not -- I don't have an opinion on that at the present time.
QUESTIONS BY MR. FINCH:
Q. You've never used a probe to determine the flexibility of an asbestos fiber under a microscope?
A. No, that has never been necessary in my research. I've analyzed many amphiboles and certainly many minerals that are asbestos, but it was apparent microscopically that those phases were asbestos -- or they were identified to me as such, so that I had no need to verify them by testing their flexibility.
Q. And so am I correct that ISO 22262-1 and ISO 22262-2 don't set forth any steps or methodologies that a scientist or analyst should follow to determine either the tensile strength or the flexibility of a fiber that is being analyzed under either of those protocols?
A. You know, I'd have to go back and re-read them with that question in mind. I would be happy to take the time to do that. I don't recall.

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Q. You don't know whether they do or not as you sit here today?
A. I don't recall.
Q. What is your understanding of what mines Johnson & Johnson got its talc from?
MR. FROST: Objection.
THE WITNESS: All I know is that they came from China -- hang on, let me find my figure -- and Vermont and another place, which I don't recall.
QUESTIONS BY MR. FINCH:
Q. Do you have the chronology as to when Johnson & Johnson got its talc from Vermont versus when it got its talc from China versus when it got its talc from Italy?
A. Yes, I believe those data are noted in my spreadsheet, and I believe that the data themselves are in the Longo and Rigler reports. I can't recall exactly where they came from.
Q. Do you have an understanding of how many different mines Johnson & Johnson got talc from that went into baby powder from

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Vermont?
A. No. None.
Q. So you don't have any understanding as to whether the talc in Vermont came from the Hammondsville mine, the Hamm mine, the Rainbow mine or the Argonaut mine?
MR. FROST: Objection.
THE WITNESS: Or anywhere else, no.
(Dyar Exhibit 8 marked for identification.)
QUESTIONS BY MR. FINCH:
Q. Let's mark this as Exhibit 8.
This is Dr. Longo's second supplemental report, which is dated February 1, 2019.
Professor Dyar, Darby Dyar, have you seen -- you've obviously reviewed Dr. Longo's report in the backup materials dated January 16th, correct?
A. Yes, I've typed all these numbers into a spreadsheet.
Q. Okay. And did you also review the February 1st report which contained a

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couple of corrections to his earlier report?
A. I believe so, yes.
Q. Okay. I'm going to use -- I'm not going to mark the entire 2,000-page January report as an exhibit to save trees. I think we all know that's the report that you were looking at when you wrote your expert witness report, correct?
A. One of the reports, yes.
Q. On page 8 of Dr. Longo's report, which we've marked as Darby Dyar 8 -- let me know when you're there.
A. I'm there.
Q. Under ATEM, four pages down -- four paragraphs down, Drs. Longo and Rigler state, "Two different regulated amphibole asbestos types were found. These were the tremolite asbestos solid solution series amphiboles, which includes tremolite, winchite, richterite and actinolite, and the anthophyllite asbestos solid solution series that includes anthophyllite, iron-rich anthophyllite, ferro-anthophyllite, cummingtonite and grunerite."
Do you see that?

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A. I see that that's what the report says, yes.
Q. Okay. What is the anthophyllite asbestos solid solution series?
A. So if you return to my document, Table 1 has a handy table with those mineral formulas in it.
So if you look at the formula of anthophyllite, which is Mg7(Si8O22)(OH)2, you see it's a solid solution with some other amphiboles in this list that include iron, such as grunerite.
Q. And what does that mean?
A. It means that there can be a continuous range of chemical substitution between those two end numbers.
Q. And do you know whether all the materials in the anthophyllite asbestos solid solution series are treated as regulated asbestos or not?
MR. FROST: Objection. Form.
THE WITNESS: I know that the six stated regulated amphibole asbestos species are the ones given in my report.

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QUESTIONS BY MR. FINCH:
Q. My question was a little different.
Do you know if the -- all of the materials in the anthophyllite asbestos solid solution series are treated as regulated asbestos?
MR. FROST: Objection.
MR. CHACHKES: Objection.
THE WITNESS: I'm telling you that what I know is that the regulated asbestos species are the ones given in my report.
QUESTIONS BY MR. FINCH:
Q. One of which is anthophyllite, correct?
A. Yes, as IARC 2012 identifies them, the five amphibole minerals: actinolite, amosite, anthophyllite, crocidolite and tremolite.
Q. Okay. My question is a little bit different.
The anthophyllite asbestos solid solution series includes anthophyllite, iron-rich anthophyllite, ferro-anthophyllite,

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cummingtonite and grunerite, correct?
A. I'd have to look up -- look that up. I'm sure that the amphibole chemistries are so complicated -- as you will recall from my report, there are some 80-odd amphibole species with solid solutions intermixed among them.
So, yes, these species are all related, but so are many other amphibole species as well.
Q. Are you familiar with Klein and Hurlbut's Manual of Mineralogy?
A. Yes.
Q. What is that?
A. It's a very old mineralogy textbook.
(Dyar Exhibit 9 marked for identification.)
QUESTIONS BY MR. FINCH:
Q. Let's mark this as Exhibit 9.
On page 489 of Exhibit 9, there is a diagram there.
MR. FINCH: And can I have the Elmo --
VIDEOGRAPHER: Sure.

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MR. FINCH: -- so people who are not privy to the document can see what I'm talking about?
THE WITNESS: So what year was this particular edition of Hurlbut and Klein published?
MR. FINCH: Sometime in the 1980s, I believe, but --
THE WITNESS: So this would not include the revision of amphibole nomenclature that was approved by the International Mineralogical Society, or association, I don't know, sometime in the '80s by Hawthorne, et al., in which the amphibole nomenclature was extensively rewritten. So this definition in these documents are significantly out of date.
QUESTIONS BY MR. FINCH:
Q. Okay. My question is: Do you know whether or not cummingtonite, ferro-anthophyllite, iron-rich anthophyllite and grunerite are treated as regulated asbestos by the United States EPA, OSHA or any other governmental organization?

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MR. CHACHKES: Objection.
MR. FROST: Objection.
THE WITNESS: I am only aware of these six amphibole species given in my report to be regulated asbestos minerals.
QUESTIONS BY MR. FINCH:
Q. Do you agree that iron-rich anthophyllite is found in the anthophyllite asbestos solid solution series?
A. If indeed that is still the name of the mineral species -- I'm inferring what you mean by that -- I would say that possibly it would be part of the solid solution series.
Q. Am I correct that cummingtonite and anthophyllite have the same chemical structure?
A. All amphiboles have the same chemical structure in many ways. There are slight deviations depending on the composition.
Q. All right.
A. So just as all the other end amphibole minerals in the amphibole group

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have the same structure, yes, they have the same structure.
Q. Okay. Looking at Table 1 on page 9 of your report, am I correct that anthophyllite and cummingtonite have the exact same chemical makeup in terms of the chemical formula?
A. That is correct.
Q. All right. Do you know whether cummingtonite is treated as regulated asbestos by any governmental or international organization?
MR. CHACHKES: Objection.
THE WITNESS: I am aware only of the six regulated amphibole -- or six regulated asbestos -- potential asbestiform minerals that are given in my report.
QUESTIONS BY MR. FINCH:
Q. So is the answer to my question, no, you don't know one way or the other whether cummingtonite is treated as a subset of anthophyllite for regulatory purposes?
MR. LOCKE: Objection.

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MR. CHACHKES: Objection.
MR. FROST: Objection.
THE WITNESS: My goal in reviewing this report was to examine the methodology. My goal was not to opine on amphibole regulations.
QUESTIONS BY MR. FINCH:
Q. I take it you have no opinion as to whether cummingtonite can cause mesothelioma or ovarian cancer if it's inhaled?
MR. FROST: Objection.
THE WITNESS: I have no opinion.
QUESTIONS BY MR. FINCH:
Q. Would you agree with me that -- let me back up.
Do you know what accessory minerals were found in talc from the Vermont mines from which Johnson & Johnson obtained the talc for its baby powder?
MR. FROST: Objection to form.
THE WITNESS: No, I have no idea.

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QUESTIONS BY MR. FINCH:
Q. Do you know what accessory minerals are typically found in talc mines?
MR. FROST: Objection. Form.
THE WITNESS: No, I have no idea. I am familiar in the general sense with the rock types, metamorphic rock types, in which talc occurs. I know it's a low-grade metamorphic mineral, but that's -- I know nothing specifically about Vermont.
QUESTIONS BY MR. FINCH:
Q. Can talc be contaminated with asbestos?
MR. FROST: Objection to form.
THE WITNESS: I have no opinion on that. I'd have to research that question.
QUESTIONS BY MR. FINCH:
Q. From what parts of the world has talc been found to be contaminated with asbestos?
MR. FROST: Objection.
THE WITNESS: Based on the information in my report and the

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samples tested by Drs. Longo and Rigler, there is no evidence to suggest that any samples tested by Drs. Longo and Rigler are contaminated with asbestos.
QUESTIONS BY MR. FINCH:
Q. That's not my question. From what parts of the world has talc been found to be contaminated with asbestos, as discussed in either the peer-reviewed literature or in publications by entities such as IARC?
MR. LOCKE: Objection.
MR. FROST: Objection.
THE WITNESS: I have no knowledge of that because I was not asked to review talc paragenesis. I was asked to review methodology only.
QUESTIONS BY MR. FINCH:
Q. You mentioned IARC in response to one of my questions a few minutes ago. What is that?
A. It's yet another international standard report. I'd have to take a look at that report to give you a more specific

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answer.
Q. Do you understand that IARC is the International Agency for Research on Cancer?
A. I had no idea that's what it stood for. I don't recall that from when I reviewed the report.
Q. Were you aware that IARC concluded that talc contaminated with asbestiform fibers can cause mesothelioma and other asbestos-related cancers?
MR. FROST: Objection to form.
THE WITNESS: I'm not aware of that. If it was in the report, I don't recall it. I was specifically reading the report for relevance to my methodology inquiries.
QUESTIONS BY MR. FINCH:
Q. Do you agree or disagree that asbestos was mined in Vermont?
A. Assuming that the information that was given to me was correct, then I think some of the talcum powder samples that I studied were mined in Vermont, but I have no knowledge of whether asbestos was found or

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mined in Vermont.
Q. Do you have -- do you agree or disagree that talc mines in Vermont have been found to contain asbestos?
MR. FROST: Objection.
MR. LOCKE: Objection.
THE WITNESS: Based on my reading of the data in Drs. Longo and Rigler's reports, there is no evidence to suggest that there is any asbestos in any of the talcum powder samples they studied, some of which I understand are from Vermont.
QUESTIONS BY MR. FINCH:
Q. Do you agree or disagree that talc mines in Vermont owned by Johnson & Johnson or its subsidiary, Windsor Minerals, have been tested and found to contain trace amounts of asbestos?
MR. CHACHKES: Objection.
THE WITNESS: I have no knowledge of that. Please support your supposition.
(Dyar Exhibit 10 marked for identification.)

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QUESTIONS BY MR. FINCH:
Q. Professor Darby Dyar, have -- you've seen this publication before, correct?
A. I have seen this paper, yes. I believe I cited it, 1991, yes.
Q. When did you first review this publication?
A. For the purposes of assessing the so-called Blount method cited by Dr. Longo.
Q. All right. The title of the paper is "Amphibole Content of Cosmetic and Pharmaceutical Talcs"?
A. That is correct. That is the title.
Q. And this was published in a peer-reviewed journal and describes a methodology for preparing talc in order to analyze whether or not there's asbestos fibers or asbestos bundles in it, correct?
A. Its goal is to determine the number of amphibole particles in a sample, yes.
Q. And the author analyzes various samples of talc under PLM, correct?

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A. So give me a few minutes, and I'll take a look at this paper and refresh my memory so I can answer your question.

So in this case, these samples are being analyzed on a microscope slide, which implies that in fact he is using polarized light microscopy, yes, although in point of fact he doesn't state that.

Q. You mean that it's Alice Blount. She --

A. Well, she does not state that. Sorry, Alice.

Q. Are you aware of the origin of the samples that Professor Blount was testing?

A. It says five deposits in Montana, three in Vermont, and one each in North Carolina and Alabama.

Q. And also finished products, correct?

A. That's what it says here: In addition, four talcs from outside the US but available on the US market were included in this study.

Q. Have you reviewed Dr. Blount's

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deposition taken in connection with ovarian cancer litigation?

A. No.

Q. Have you reviewed Dr. Blount's correspondence with Johnson & Johnson where she tells Johnson & Johnson she identified asbestos fibers in baby powder?

MR. FROST: Objection.

THE WITNESS: No, I have not reviewed such a document.

QUESTIONS BY MR. FINCH:

Q. Dr. Longo -- let me see if you agree with this description of generally the various steps that Dr. Longo and his lab followed to analyze the samples of talc he obtained from Johnson & Johnson or Imerys.

First of all, he got samples of talc from either Johnson & Johnson or Imerys.

Do you have that understanding?

MR. CHACHKES: Objection.

THE WITNESS: I honestly don't recall where he said he got them. I recall seeing a chain-of-custody paperwork. I wasn't paying attention to where he got the samples from.

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QUESTIONS BY MR. FINCH:

Q. Okay. You don't offer any criticisms of either the chain of custody or the conclusion that what he was, in fact, analyzing was talc that came from either Johnson & Johnson finished products or the mines from which Johnson & Johnson finished products were made?

MR. FROST: Objection.

THE WITNESS: I would say that it is unclear to me whether the samples he got were from eBay, whether they had been opened, whether they had been contaminated, so it's unclear to me exactly what he was testing.

I know what he asserts in his report, but I -- it's unclear to me that he was testing unopened, pure, pristine talc as marketed.

QUESTIONS BY MR. FINCH:

Q. Were you aware that there was a procedure in this MDL for samples to be split between Johnson & Johnson and Dr. Longo from historical museum samples that Johnson & Johnson had maintained?

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MR. FROST: Objection.

THE WITNESS: Yes, certainly one of the documents is called historical samples, so I'm aware that the samples came from the museum and, therefore, are unknown sources in terms of being opened or being pure.

QUESTIONS BY MR. FINCH:

Q. But you don't criticize or take issue with Dr. Longo's conclusions that what, in fact, he is testing is talc that came from Johnson & Johnson finished products or Johnson & Johnson mines, correct?

MR. CHACHKES: Objection.

MR. FROST: Objection.

THE WITNESS: I do indeed have problems with that statement because you don't know if those samples, having been stored in a museum or in someone's cupboard, were opened and exposed to contamination. So I don't know that.

QUESTIONS BY MR. FINCH:

Q. Well, you certainly didn't comment upon it in your report, correct?

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A. It wasn't relevant to my question of whether the methodology that he used to analyze the samples was appropriate or not.
Q. All right. So he got the samples from Johnson & Johnson in this litigation, the samples that are analyzed in his February 1, 2019 report. And then for many of the samples, he used what is called the Blount preparation method, correct?
A. That is correct.
Q. All right. I read through your report, and I didn't see any criticisms related to the way in which he applied the Blount preparation method to prepare the samples for analysis; is that correct?
MR. LOCKE: Objection.
THE WITNESS: Correct, there is nothing in my report that criticizes his use of the Blount method.
QUESTIONS BY MR. FINCH:
Q. Do you agree that use of the Blount method to prepare a talc sample in order to analyze whether or not it's contaminated with asbestos is a reasonable

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and reliable thing for a scientist to do in testing talc for the presence of asbestos?
A. I actually would say I do not agree with that. In fact, I do not agree with the results in the Blount paper.
For example, Figure 1 in Blount's paper which -- or Figure 2, which purports to give the specific gravities of talc and amphibole, is just simply wrong. Those ranges are far wider and far more overlapping than she is apparently knowledgeable of.
So in my mind, the simple fact that the densities of these minerals overlap each other a great degree renders the Blount method to be difficult to use, at best.
Q. But you didn't, in your report, criticize Dr. Longo's use of the Blount method; is that correct?
A. In my written report I did not state that criticism, no.
Q. Okay. And am I correct that ISO 22262-2 describes a gravimetric --
A. Gravimetric, yes.
Q. -- method to separate materials

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and talc out for purposes of analyzing whether or not they contain asbestos?
A. It certainly contains something that indicate -- tells how to separate out things with different densities, and it talks specifically about asbestos.
And I note that the refractive index, or the density, of the liquid that they say to use is different than the one used in the Blount paper. One is 1 point -- I don't remember, but they're different.
So Dr. Longo did not follow what's in the ISO report. He followed what's in the Blount report.
Q. He reviewed what's in the Blount peer-reviewed paper, correct?
A. He used the 1.610, I believe, density method.
Q. Were you aware that the Blount paper was cited in the IARC publication you were referring to earlier relating to talc with asbestiform fibers?
MR. FROST: Objection.
THE WITNESS: I don't recall that.

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QUESTIONS BY MR. FINCH:
Q. Do you agree with me that IARC generally only cites to reputable papers in its work?
MR. FROST: Objection.
MR. CHACHKES: Objection.
THE WITNESS: I have no independent knowledge of IARC, so I can't really answer that question.
QUESTIONS BY MR. FINCH:
Q. Nonetheless, the Blount methodology as described in her paper was published in a peer-reviewed journal, correct?
A. I've never encountered this journal before, but I'm assuming that if it's called a journal, it is indeed peer reviewed. But I'd have to corroborate that. I don't know anything about this journal. It's not a highly ranked journal.
Q. What systematic study have you done to determine whether Environmental Health Perspectives is ranked highly or not ranked highly?
MR. CHACHKES: Objection.

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THE WITNESS: It would be a simple matter to log on to the Web of Science and determine the rating of that journal, but I have not done that. I'm not in the habit of establishing the ratings on all the papers that I read.

I am very familiar with the premier journals in the subject of mineralogy, and that's not one of them.

QUESTIONS BY MR. FINCH:

Q. Would you agree with me there are many different disciplines of science that bear on the question of what is asbestos?

MR. FROST: Objection. Vague.

MR. CHACHKES: Objection.

THE WITNESS: No, I wouldn't agree with that.

I would say that the definition of asbestos is fairly straightforward, as given in my report, and it is firmly grounded in both mineralogy and the other fields that are cited.

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QUESTIONS BY MR. FINCH:

Q. At the end of page 230 in her paper, Dr. Blount writes that "In addition, the tendency to bring down a disproportionate number of larger particles has the advantage that with true asbestiform amphiboles one generally sees some particles showing bundles of fibrils, which removes any doubt about the nature of the amphibole."

Do you see that?

A. I see that the paper says that, yes.

Q. Do you agree that if you find bundles of fibrils that are amphibole in nature, it makes it more likely than not that what you're looking at is asbestiform amphibole?

A. No, I do not agree with that statement.

Q. Why not?

A. First of all, you'd need to define "bundle." And to my knowledge, the way asbestos is deformed -- defined does not include the term "bundle," as stated in the definition I've given previously in this

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deposition.

MR. CHACHKES: By the way, we've been going about an hour. Maybe at some point take a break.

QUESTIONS BY MR. FINCH:

Q. Do you agree or disagree that the most common asbestos mineral found as a contaminant of talc is tremolite asbestos?

MR. FROST: Objection. Form.

THE WITNESS: No, I do not agree with that. I have no knowledge of that. In fact, based on the Longo, Rigler reports, I have no evidence that suggests that any asbestos minerals are found in talc.

QUESTIONS BY MR. FINCH:

Q. Do you have an opinion one way or another as to whether talc can be contaminated with anthophyllite asbestos or tremolite asbestos when it is mined out of the ground?

MR. LOCKE: Objection.

THE WITNESS: I know nothing about mining practices. I'm not a mining geologist, so I have no opinion

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on that.

QUESTIONS BY MR. FINCH:

Q. You have no opinion about whether or not the -- you haven't reviewed all of the data that exists in the world as to testing done on Johnson's baby powder or the talc that went into Johnson's baby powder to determine whether or not it contained asbestos, correct?

MR. LOCKE: Objection.

MR. CHACHKES: Objection.

THE WITNESS: My role here was to evaluate the methodology used by Drs. Longo and Rigler, so such an assertion would be far, far outside of what I researched and was asked to do.

QUESTIONS BY MR. FINCH:

Q. Okay. You are a geologist by training, correct?

A. Correct.

Q. As a matter of geology, do you agree with me that talc can be contaminated with accessory minerals, minerals that are not talc?

A. Of course.

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Q. You agree with me --
A. Metamorphic rocks that contain talc often have other minerals in them, yes.
Q. You agree that talc can be contaminated with anthophyllite asbestos?
MR. FROST: Objection.
THE WITNESS: I have no specific knowledge of the assemblages that are stable with talc. I only know that it's a low-grade metamorphic mineral, but I know nothing about the other phases that are present. I'm not a metamorphic geologist.
QUESTIONS BY MR. FINCH:
Q. So you don't know one way or another whether or not talc can be contaminated with anthophyllite asbestos; is that fair?
MR. LOCKE: Objection.
THE WITNESS: I have no knowledge of the natural parageneses of talc, beyond the fact that it's a low-grade metamorphic mineral.
QUESTIONS BY MR. FINCH:
Q. Do you agree or disagree with

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the fact that talc can be contaminated with anthophyllite asbestos or tremolite asbestos?
MR. CHACHKES: Objection.
THE WITNESS: I disagree with that. I don't know that that's a fact, and I have not researched that personally, so I have no opinion on it. But I do not certainly consider it a fact.
QUESTIONS BY MR. FINCH:
Q. What tools would you use to test a sample of talc to determine if it contains asbestos?
A. Again, I was not asked to rule on that, but if I were to do testing, I would probably follow some combination of the Su protocols and those articulated in the Yamate document, which was exhibit whatever.
Q. What are the tools that you would use?
I'm not asking about the protocols you would follow. What tools?
A. I would ideally use multiple zone axis determinations combined with EDS to rule out or confirm the presence of calcium,

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which determines in part whether it's monoclinic or orthorhombic. And I would also use polarized light microscopy on multiple grains to determine the -- in part the chemistry of the particle. And then I would sample populations of particles to determine them in an ideal sense.
But this would be only something I would do in the laboratory, in the sort of -- in a careful study with my students.
Q. Okay. So you would -- you mentioned you would use multiple zone axis analysis.
You're talking about SAED, correct?
A. Correct.
Q. So you would use -- one tool you would use is an electron microscope, correct?
A. Uh-huh. Yes.
Q. Then you would do EDS, EDXA, to determine the chemistry, the elemental chemistry, of a material, correct?
A. I would use it to determine

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whether or not calcium was present, yes.
Q. All right. And that is, again, using a transmission electron microscope, correct?
A. Or an SEM, yes.
Q. And does it matter in which order that you would do steps 1 and 2, meaning would you first -- does it matter whether you first analyze it using EDS, EDXA, or whether you first analyze it using SAED?
A. I would think it would not -- it certainly doesn't matter.
Q. The third step, you said, would be to analyze it using a polarized light microscope, correct?
A. Yes.
Q. Does it matter in which order you would analyze it using a polarized light microscope?
Meaning would you do SAED or an EDS before or after the PLM, or does it not matter?
A. Well, you presumably wouldn't be able to do it on the same particle because the PLM is usually done on a microscope slide

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and the TEM is done on a grid. So order is kind of irrelevant since it's different particles.
Q. Different particles from the same sample?
A. Yes.
Q. Then presumably you would have photomicrographs of the particle that you're examining from the electron microscope, either images via TEM or SEM, correct?
A. In this hypothetical situation, yes.
Q. I mean, this hypothetical situation is I'm asking you to analyze a sample of talc to determine whether it has asbestos in it. You would take pictures with your electron microscope that are called photomicrographs to determine what the structure looked like visually, correct?
MR. LOCKE: Objection.
THE WITNESS: Well, in point of fact, you could also take photomicrographs with a polarized light microscope.

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QUESTIONS BY MR. FINCH:
Q. And --
A. If the particles are big enough.
Q. Right.
And in those photomicrographs, either using TEM or PLM, you have a picture of the structure that you're analyzing, correct?
A. You have a two-dimensional image of a particle viewed from one angle, yes.
Q. And is it left to -- is there any written protocol or peer-reviewed literature that tells an analyst or scientist what it is to photograph or when to take the photomicrograph of the particle, either by PLM or TEM or SEM?
MR. FROST: Objection.
THE WITNESS: Well, for example, if you look in the Su paper that I've cited here, it talks pretty specifically about exactly how you would rotate the grain and examine it from different perspectives. So,

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yeah, there are written protocols about that.
And, of course, basic polarized light microscope use is written up in -- ubiquitously in textbooks, including the outdated one that you gave me a section of.
MR. CHACHKES: So I asked for a break about ten minutes ago. Are we getting near a point where we can break?
MR. FINCH: Yeah. Two more questions.
MR. CHACHKES: Okay.
QUESTIONS BY MR. FINCH:
Q. So you mentioned the tools that you would use would be to take your sample and, using an electron microscope, perform SAED and EDS, EDXA, on it; then use a polarized light microscope to analyze a different particle in the same sample. Correct?
MR. FROST: Objection. Misstates testimony.
MR. CHACHKES: Objection.

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THE WITNESS: By definition, if you look at something on a polarized light microscope, generally speaking you're looking at something on a glass slide, not a TEM grid, yes.
So if you're going to do multiple analyses of that sort, you would be using different particles from the same sample.
QUESTIONS BY MR. FINCH:
Q. And then you would have populations of -- an analysis of populations of particles?
A. If you analyzed enough samples as is recommended in many of these protocols, you would have -- you could have -- potentially have a population, yes.
MR. FINCH: Okay. This is a good stopping point.
VIDEOGRAPHER: Okay. Stand by, please. Remove your microphones. The time is 11:31 a.m. Off the record.
(Off the record at 11:31 a.m.)
VIDEOGRAPHER: Okay. We are back on the record. The time is

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11:47 a.m.
QUESTIONS BY MR. FINCH:
Q. Have you ever done any consulting work for Johnson & Johnson prior to your engagement in this case?
A. No.
Q. Have you ever done any consulting work for Imerys, Imerys Talc America, Imerys NA or any of their affiliated companies prior to your engagement by Johnson & Johnson in this case?
A. No.
Q. Have you ever done any consulting work for Colgate-Palmolive?
A. No.
Q. Have you ever done any consulting work for W.R. Grace?
A. No.
Q. Have you ever done any consulting work for the RJ Lee Group?
A. No.
Q. Have you ever done any consulting work for Scotts fertilizer company?
A. No.

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Q. Have you ever done any consulting work for BNSF Railway?
A. No.
Q. Have you ever been engaged to test vermiculite or to determine whether or not it contains asbestos?
A. No.
Q. Have you ever been hired by any entity to test a vermiculite-finished product to determine if it contains asbestos?
A. No.
Q. Have you ever been hired by any governmental entity to test any substance to determine whether it contains asbestos?
A. No.
Q. Have you ever been retained by any company that either mined talc or sold talc-containing finished products to analyze whether or not it contains asbestos?
A. No.
Q. All right. On page 1 of your report, you're talking about EDS mineral chemistry, correct, at the bottom of the page?
A. Yes.

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Q. In the -- I believe I might have asked you this before, but I'm not sure I remember the answer to it.
Have you ever tested an NIST reference sample of asbestos using EDS, EDXA to determine what the EDS spectra looks like for tremolite or anthophyllite?
A. No, but that wouldn't be necessary. EDS is a fairly basic technique. You could even synthesize the spectrum of those minerals and determine what they looked like, so it wouldn't be necessary to do it myself personally.
Q. Would you agree with me that the transmission electron microscope, when it analyzes a reference samples of asbestos using EDS or EDXA, will -- is capable to print out an EDS spectra from that microscope that shows what the chemical makeup of the reference sample of asbestos is?
A. Certainly an EDS spectrum can show you the presence or absence of particular elements, and it can give you a rough sense of how much of each is present.
Q. In the third bullet point you

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state, at the bottom of the page, "They," referring to Longo and Rigler, "deliberately choose not to generate quantitative numbers that would more accurately determine the chemical compositions, which is the very purpose of an EDS analysis of an unknown mineral."
Do you see that?
A. Yes. I wrote that.
Q. What generally accepted standards require the printout of quantitative data similar to Figure 7 in your report in order for a scientist or analyst to analyze the chemical structure of a mineral to determine whether it's consistent with asbestos or not?
A. That was a big mouthful. Let me review that sentence.
So as articulated by Newbury and Ritchie in their report about EDS spectroscopy and doing it accurately, it is important to do the calculations based on the peak areas with the appropriate corrections in order to get even semi-quantitative data out of an EDS spectrum.

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Q. Does anything in ISO 22262-1 or 22262-2 or Yamate require the quantitative data like that shown in Figure 7 be generated in order for an analyst to analyze the chemical structure of a particle that could be asbestos?
A. I don't recall. I'd have to go back and review them. But I'm guessing that because 22262 is about microscopic methods and 222-1 {sic} is about polarizing light microscopy, that neither one of them has much to say about EDS. I honestly don't recall which of those ISO documents talks about EDS.
Q. Isn't it true that ISO 22262-1 has an extensive discussion of analysis by TEM, quantitative analysis by TEM, of -- qualitative analysis by TEM of EDXA spectra?
A. As I said, I did not recall that, but I have it in my hand now and I'll be happy to take a look.
Q. Page 33.
A. Yes, I see it talks about --
MR. FINCH: Can I have the Elmo?
THE WITNESS: -- qualitative

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analysis by TEM, yes.
QUESTIONS BY MR. FINCH:
Q. All right. Can you point me to any ISO standard or anywhere in Yamate where it says that it's necessary for an analyst to have quantitative data like that shown in Figure 7 in your report in order to analyze the chemical structure of an asbestos mineral?
A. So the definition of asbestos requires that a mineral be one of the specific six regulated mineral species. And in order to determine if a mineral is among the six regulated mineral species, it is necessary to know the chemical composition and the crystal structure, as I describe in my report.
Therefore, it follows that it would be useful to know the chemical composition in order to confirm whether one of the six regulated mineral species is present. And as articulated here, the TEM analysis is only qualitative.
Q. And am I correct that in Yamate, for example, it states, "Energy-

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dispersive X-ray analysis as used in asbestos analysis is semi-quantitative at best"?
Do you see that?
A. That is correct, but --
Q. Do you agree with that?
A. But let me point out that in his deposition, Dr. Longo says very specifically that it's quantitative, and that is exactly what I'm disagreeing with.
Q. Are you aware of any ISO standard or EPA publication that requires the printout of quantitative data like you have in Figure 7 in your report in order to analyze the X-ray spectra of an asbestos -- or potentially asbestos chemical?
A. I am aware that analysis of ISO standards and under EPA requirements require that the mineral species be identified. And in order to identify the mineral species, it is necessary to have a quantitative -- as quantitative as possible chemical analysis.
Q. Isn't it true that ISO 22262-1 says nowhere that you have to have a quantitative analysis, or the quantitative printouts like you have in Figure 7 in your

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report, in order to do a valid analysis of the chemical spectra of an asbestos particle?
A. It is true that ISO 22262-1 indicates that the asbestos is defined as one of specific mineral species. And so in order to determine if something is among a specific mineral species, you would have to know the chemical composition.
Q. But it doesn't require you to have quantitative data in the level of detail that you show in Exhibit 7 to determine the chemical structure of the mineral, correct?
A. It would be the chemical composition of a mineral.
Q. The chemical composition of the mineral?
A. It requires that you know the chemical composition well enough to identify the sample as one of the six regulated mineral species.
Q. And do you have any view one way or another whether the analysts in Dr. Longo's lab, or Dr. Longo himself, is sufficiently familiar with the chemical composition of the six regulated types of

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asbestos that they can determine based on looking at a semi-quantitative EDXA spectra whether or not the material they're looking at has a chemical signature consistent with asbestos?
A. I would say absolutely not, they do not have -- because it's impossible to look at -- no matter how many thousands of EDS spectra you've looked at, it is impossible to look at an EDS spectrum and, without analyzing it, obtain quantitative data as Dr. Longo purports to do.
Q. Okay. In ISO 22262-1 -- do you have that?
A. Got it.
Q. You can do EDS, EDXA, by SEM or TEM, correct?
A. Depends on the instrument, yes.
Q. All right. Would you turn to Annex F.
A. Yes.
Q. All right. Would you agree with me that pages 58, 59, 60, 61, 62 all show EDS, EDXA spectra for samples of tremolite, anthophyllite and the other

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asbestos varieties?
A. That is what this document claims to show, yes.
Q. And you agree with me that nowhere in these printouts of what the chemical signature is using EDS, EDXA, does it have quantitative data like that shown in Figure 7 in your report?
A. It is correct that those are not given; however, in the case of these reference standards, these have been independently analyzed for chemistry and, therefore, the chemistry is already known. And there is no need to determine the chemistry by this semi-quantitative EDXA analytical method, which is why it probably isn't shown here.
Q. Isn't it the case that what this ISO 22262-1 is all about is determining when you've got a bulk material where you don't know whether it has asbestos or not in it, to do an EDS or EDXA to compare the data you get from the bulk material to the standard EDS, EDXA spectrum contained in Annex F?

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A. No, sir. It says on --
MR. LOCKE: Objection.
THE WITNESS: -- page 1 of this document that this document is appropriate for the analysis of -- the quantitative -- qualitative analysis identification of asbestos in specific types of manufactured asbestos-containing products and commercial minerals.
So I would say that these patterns have been developed for use in situations where you already know that what is present is asbestos, and you're trying to determine which of the six asbestos minerals is present, which is clearly not the case in the study of talc.
QUESTIONS BY MR. FINCH:
Q. Would you agree with me, or do you know, whether or not insulation can be asbestos-containing or non-asbestos-containing?
MR. CHACHKES: Objection.
THE WITNESS: I don't know

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anything about that.
QUESTIONS BY MR. FINCH:
Q. Okay. Would you agree with me, or do you know, whether ISO 22262 can be used to test insulation, where you don't know whether it has asbestos in it or not, to determine whether or not the bulk material that you're looking at contains asbestos?
A. I believe it says asbestos-containing insulation.
And it goes on to talk about -- in the introduction about asbestos-containing insulation. For example, "A large proportion of the chrysotile product produced was used in asbestos cement products. Materials containing high proportions of chrysotile asbestos were used in buildings and in industry."
So that's what it says here.
Q. Isn't it true that in the scope on page 1 of the document, this part of ISO 22262 specifies methods for sampling bulk materials and identification of asbestos in commercial bulk materials?
It doesn't say anything about

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asbestos-containing bulk materials, correct?
A. It indeed says it specifies methods for sampling bulk materials and identification of asbestos in commercial bulk asbestos. That's what it says here, yes.
Q. All right. Do you have the understanding one way or another that this is the methodology a scientist should follow if he has a bulk material of insulation that he doesn't know whether it has asbestos in it or not, to follow this methodology to determine whether there's asbestos in the material or not?
A. To which methodology are you referring? The entire document?
Q. ISO -- yes.
A. This document and the extended versions 2 and 3 are intended for that purpose. That's what it says they're intended for.
Q. Okay. Would you agree with me that Annex F has the X-ray spectra for tremolite on page 61?
A. It does include spectra of samples of these minerals, yes. Certainly

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these are not necessarily representative of all possible examples of these minerals, but they are individual standard reference materials of these particular individuals {sic}.
Q. Are you aware whether tremolite was ever used as part of any -- an asbestos-containing product, intentionally designed to be part of an asbestos-containing product?
MR. FROST: Objection.
THE WITNESS: I have no knowledge of that.
QUESTIONS BY MR. FINCH:
Q. Do you recognize the Yamate method as a method to analyze -- to determine whether or not there is or is not asbestos in either a bulk sample or in the air?
A. The Yamate method is, strictly speaking, a method for measurement of airborne asbestos.
Q. And is it part of the method to determine whether or not -- whether asbestos is there or not?
A. So let's take a look at level 3

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analysis where it specifically focuses on the example of asbestos. I believe it's level 3. Let me see if I can find that.
Sorry, what was your question?
Q. My question is, isn't the entire Yamate protocol something that is used to determine whether or not asbestos is in a material or not?
A. Well, the title of the document is "Methodology for Measurement of Airborne Asbestos By Electron Microscopy."
So the level 3 as specified in this document details the use of quantitative SAED analysis from two different zone axis orientations, et cetera, et cetera.
Q. Right.
But before you get to quantitative level 3 analysis, you do level 2 analysis, correct?
A. That's correct.
Q. And level 2 analysis, you're trying to determine whether or not there is asbestos in the material or not, correct? May have asbestos in it, may not?
A. At -- at significant -- at

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significant levels, yes.
Q. And it doesn't require the analyst, in looking at an EDS, EDXA spectrum, to have the quantitative data like that shown in Figure 7 in your report to determine the chemical composition of the material he or she is analyzing, correct?
A. Well, in point of fact, level 2 is level 1 plus chemical analysis. And it says that -- in level 2 you're talking about a process of elimination used to categorize amphibole fibers, identify the ambiguous fibers in concern or validate level of chrysotile fibers. So it all builds.
What was your question?
Q. My question is, is there anything in the Yamate document that requires an analyst to have quantitative data like Figure 7 in your report for the EDS, EDXA analysis he or she performs on a material to determine whether its chemical composition is consistent with asbestos?
A. Well, I guess maybe read the question again here.
The Yamate document is about

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confirming whether it's one of the specific asbestos mineral species. And so to the extent that it is necessary to have chemical analysis to determine whether something is one of the species, then, yes, it does imply that you need to have quantitative EDS data.

Q. Where? Where? Point me to where it says you have to have quantitative EDS data.

A. It says that you need to identify a specific -- whether a specific asbestiform or potentially asbestiform mineral species is present. And to me, that implies that you need to know what the chemistry is because otherwise you couldn't tell.

Q. And isn't it correct that at page 39 of the document it states, "Energy-dispersive X-ray analysis, as used in asbestos analysis, is semi-quantitative at best"?

A. Absolutely, yes.

Q. And it says nowhere in here that you have to have quantitative EDS or ED X-ray analysis.

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Can you point to me anywhere in this document where it says must have a quantitative data like that shown in Exhibit 7 {sic} in your report?

A. So I would say that nowhere in this document does it says that you must have a quantitative printout, but certainly that information is necessary to determine whether something is a particular composition.

So again, referring back to my report, the goal of Drs. Longo and Rigler is to confirm the presence of one of the six regulated asbestiform -- potentially asbestiform minerals and whether or not they are present in the talcum powder. And the EDS data that are presented in there do not come anywhere close to determining that.

MR. FINCH: Can I have the Gunther paper?

(Dyar Exhibit 11 marked for identification.)

QUESTIONS BY MR. FINCH:

Q. This is a paper by Mickey Gunther that you cite in your report?

A. Yes, I use the figures in my

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report.

Q. Published in the peer-reviewed literature?

A. Not a commonly cited journal, but, yes.

Q. In this journal, he reports EDS data from various materials in Figures 5, 6, 8?

A. Yes.

Q. And in the EDS data he reports, for example, in Figure 6, three SEM photographs with associated EDS data of amphiboles found in soils in Washington, DC, southern Illinois, western Montana. Based on EDS data, particles A and B would be tremolite, actinolite, and C would be anthophyllite, grunerite.

Do you see that?

A. He just says based on EDS data; he doesn't say based on the EDS data shown. So my inference from this figure caption would be that he calculated the mineral compositions and drew those conclusions.

Now, he does not say that he's basing his conclusions about composition on

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the basis of these images alone.

Q. Does it say anywhere in the paper that he calculated the quantitative EDS measurement?

A. He doesn't need to. It is -- it is extraordinarily rare for someone to acquire an EDS pattern and not calculate the composition. So you would only need to mention that if you didn't calculate the composition.

Q. Does it say anywhere in this paper that you -- that he calculated -- he did some kind of quantitative analysis -- first of all, let's get very clear.

Nothing in this peer-reviewed paper has the kind of quantitative data relating to an EDS spectrum like that shown in Figure 7 in your report, correct?

MR. CHACHKES: Objection.

THE WITNESS: I would want to make sure there isn't some supplement that gives those numbers, but certainly in these five pages of this document he doesn't give the quantitative numbers. However, he

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does state that based on EDS data, these particles would be assigned these compositions.

So again, the norm when doing analysis with EDS is that you calculate the compositions. It would be extraordinary that he would have to go out of his way to not print them out, which is, in fact, what Drs. Longo and Rigler do. They must have disabled the default command to output compositions.

QUESTIONS BY MR. FINCH:

Q. You say the norm.

You haven't pointed me to a single document, either ISO standard, Yamate standard, peer-reviewed literature, that says that you have to print out the quantitative EDS, EDXA graph -- graphics like in Figure 7, have you, ma'am?

MR. LOCKE: Objection.

THE WITNESS: So in my report, I cite the Newbury and Ritchie paper which goes in excruciating detail of how the appropriate -- of the

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appropriate methodology for using EDS. And they talk in that at length about the different methods for making calculations that determine quantitative or semi-quantitative data from an EDS spectrum.

So again, Newbury and Ritchie is a good example of what is the convention in this field, which is to always acquire the EDS spectrum and then print out the compositions that are calculated by the instrument.

QUESTIONS BY MR. FINCH:

Q. Well, Dr. Gunther did not print out the calculations in his 2010 paper, correct?

MR. FROST: Objection.

THE WITNESS: He refers to the SEM data, but he does not explicitly include them, probably for reasons of space. That printout would be pretty tiny in a publication of this sort.

MR. FINCH: Can I have the Roggli paper?

(Dyar Exhibit 12 marked for identification.)

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QUESTIONS BY MR. FINCH:

Q. Professor Dyar, do you have an article entitled "Tremolite Mesothelioma" by Victor Roggli and other scientists at Duke University published in the peer-reviewed literature in 2002?

A. Yes, sir.

Q. All right. In...

A. I immediately note that the authors of this paper are medical personnel involved with pathology, and there is no indication that any of them is a mineralogist.

Q. And they are publishing in the peer-reviewed literature about various types of asbestos fibers found in human tissue, correct?

A. Well, I'd have to have some time to speed-read this paper, but the title is called "Tremolite Mesothelioma," so I'd have to assume that that's what the paper is about.

Q. And in Figure 1 -- actually, on page 448, in the second column the authors

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write, "The elemental composition of individual mineral fibers was detected by means of energy-dispersive X-ray analysis, EDXA."

Do you see that?

A. I'm looking.

Q. About halfway down, first column -- I mean, the second column.

A. Yes. So that to me implies that they output the compositions.

Q. In the paper they publish "the energy-dispersive X-ray spectra for tremolite, actinolite, anthophyllite and chrysotile. Characteristic elemental composition for each fiber type is shown. The gold piece is due to sputter coating of the sample to reduce charging artifacts."

Do you see that?

A. I see that. And it is my opinion, based on being an associate editor of the American Mineralogist for 20 years, that no self-respecting mineralogical journal would publish a figure like this. This is insufficient for any kind of chemical analysis.

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Q. So these doctors are doing chemical analysis of the asbestos fibers they found in human tissue, and they're printing out the EDXA results in Figure 1. And they do not include the quantitative data like you show in Figure 7 in your report, correct?

MR. FROST: Objection. Form.

THE WITNESS: Well, I'd have to look and make sure there isn't a supplement to this particular article, and I'd need a little more time to inspect it.

For example, I'd like to know how did they -- how did they identify the samples as asbestos in the first place. I don't see any other evidence of any other kinds of analytical techniques done in here.

I'd need to look at this much more carefully, but it is certainly my opinion that you couldn't use EDXA to identify these -- distinguish between these particular minerals.

So I -- these people may be well-respected pathologists, but this

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particular figure and these conclusions would never be published in a journal that was peer-reviewed by mineralogists.

QUESTIONS BY MR. FINCH:

Q. Are you familiar with a book entitled "Mineralogy and Optical Mineralogy" written by Melinda Darby Dyar and Mickey Gunther?

A. Indeed I am.

While we are here, let me draw your attention to page 607, where it gives the revised amphibole nomenclature, which was published in 1997 and 2004. So this is the appropriate amphibole nomenclature to be using.

MR. FINCH: Move to strike as nonresponsive to any question pending.

(Dyar Exhibit 13 marked for identification.)

QUESTIONS BY MR. FINCH:

Q. Do you recognize this as the cover page, table of contents, preface and Chapter 19 from your 2008 book?

A. Yes.

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Q. Am I correct that on pages 526, 527, 528, and in 529, 530, which is Figures 1912 to 1919, all contain EDS spectra for different minerals?

A. 526. Yes. They're simulated patterns, yes.

Q. And am I correct that none of these figures have the quantitative data like Figure 7 in your report shown in the -- in the pages of your textbook?

A. They don't include the compositions because they are simulated patterns, and simulated patterns are created by inputting a composition. So there is no need to output the composition because these are simulated patterns that are created using an input -- a specifically input composition.

MR. FINCH: Can I have the other excerpt from that book?

(Dyar Exhibit 14 marked for identification.)

QUESTIONS BY MR. FINCH:

Q. This is Exhibit 14, which is another page of that book, page 182.

What does Figure 9.17 show?

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A. It shows the EDS output of an Idaho star garnet from an SEM.

Q. Does it include the quantitative data that is shown in Figure 7 in your report?

A. No, and it wouldn't have been appropriate to include that.

First of all, the print would be too small, and second of all, the point here is to just show what an EDS spectrum looks like. It's not our intent here in this particular chapter to show -- or in this particular figure to show anything quantitative, so it wouldn't have been appropriate to include the chemistry.

So in other words, we're not trying to identify what mineral this is. We already know that it's an Idaho star garnet, so we don't need to output the chemistry to show anything about its chemical composition.

In fact, it's highly likely that we have an independent and much more accurate chemical composition from electron microprobe, and we just didn't feel it was necessary or appropriate to include it here.

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Q. On page 531 of Exhibit 13?
A. Uh-huh.
Q. Here you're not looking at a simulated material, correct?
You're looking at an approximately 5-micron-wide particle mounted on a fiber similar to the example shown in Figure 1920, images modified from Gunther's 2007 paper, correct?
A. Correct.
Q. So then you are -- in the part C, higher magnification SEM image of the same particle with analysis points for the SEM beam indicated by 1 and 2. That's an EDS spectrum there, correct?
A. Wait a minute. I'm not -- I'm not following you. Where are you?
Q. Yeah. The bottom, Figure 19.21.
A. Oh, sorry. I'm on the wrong page.
Yep.
Q. On this basis, the particle could be either a pyroxene or an amphibole; however, the refractive indices shows this

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particle is an amphibole. Choosing a species name between tremolite and actinolite would be difficult.
And the EDS of the grain there shows the chemical signature of an amphibole, correct?
A. No, I think you're misreading that. It basically says on the basis of the EDS spectrum, it could be either a pyroxene or an amphibole.
This is exactly the same point I make in the figure -- let's see -- in Figure 4 of my report where it says that on the basis of an EDS spectrum, these minerals are indistinguishable.
So then he goes on to say that because of the refractive index data, in other words, the optimal microscopy, the PLM, it is possible to constrain the identify -- the identity of this mineral to be an amphibole. But that's all you can tell.
Q. But you don't print out the quantitative data like that shown in Figure 7 of your report in this section of your textbook where you're using an EDS spectrum

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to characterize the chemical composition of a mineral, correct?
A. Again, it would not be appropriate to include that in this particular context. This is a textbook, not a research -- not a research thing. And the point of this figure is to show how difficult it is to distinguish things purely from visual examination. In other words, he's saying you really need more information.
And as I said in my report, the way to get more information would be to output the quantitative chemical data that the TEM and the SEM are easily able to provide.
So this is not an appropriate place to include chemical data.
MR. FINCH: Can I have the 2016 Gunther paper and the IC 420 document?
(Dyar Exhibit 15 marked for identification.)
QUESTIONS BY MR. FINCH:
Q. Here's Exhibit 15.
Do you have Exhibit 15 in front of you, ma'am?

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A. I do.
Q. This is -- one of the coauthors of this paper is your coauthor, Mickey Gunther?
A. I see that.
Q. Another is Dr. Roggli, whose paper we looked at a few minutes ago?
A. Yes.
Q. This is a case report of "Erionite-Associated Malignant Pleural Mesothelioma in Mexico," published in the peer-reviewed journal International Journal of Clinical and Experimental Pathology?
A. I see that.
Q. And you have two geologists publishing this paper along with Dr. Roggli, and the lead author's name I'm not going to try to pronounce because I'll butcher it. But there's about eight authors, and two of them are geologists, correct?
A. I see that, yes.
Q. And two of them are geologists that you have published with yourself, correct?
A. Yes.

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Q. And what they're doing is they are analyzing fibers found in the tissue of a human being to determine the nature of the particles in their mesothelioma, correct?
MR. LOCKE: Objection.
THE WITNESS: I need a little more time to look at this paper before I could tell you exactly what they were doing.
QUESTIONS BY MR. FINCH:
Q. Well, do you recognize Figure 3 and Figure 6 and Figure 4 as all containing EDXA or EDS spectrum of materials that they're analyzing?
A. I see that those figures do contain EDS spectra, yes.
Q. All right. So in Figure 3 on page 5727 -- and this is a scientific paper where they're reporting on finding erionite fibers in someone's mesothelioma.
That's at least the title of the paper, correct?
MR. LOCKE: Objection.
THE WITNESS: The title of the paper is "Erionite-Associated

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Malignant Pleural Mesothelioma in Mexico." That's the title.
QUESTIONS BY MR. FINCH:
Q. All right. Figure 3, part B, is the data that they choose to report in this peer-reviewed paper, "Energy-Dispersive Spectrum from an Erionite Fiber Showing Peaks for Aluminum and Silicone."
"There's a suggestion of smaller peaks for sodium and iron. Platinum peaks are from sputter contained in the sample for imaging purposes."
Do you see that?
A. I see that it says that, yes.
Q. All right. And so what that is is an EDS or EDXA spectrum of a reference sample of erionite, correct?
A. I don't see where it says that.
Q. Well, would you agree with me that the authors call it an EDS spectrum from an erionite fiber? That's what they call it in the paper?
A. That's what it says right here in the caption to Figure 3.
Q. And they don't print out the

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quantitative data that you say is required for a scientific analysis like that shown in Figure 7 in your report, correct?
A. In fact, in my report there are no independent constraints on where the particles are coming from.
In this report, it appears to me that the particles are coming from a repairman who was raised on a farm in the Mexico volcanic belt, presumably near a source of erionite. So I'd have to spend more time with this paper.
But it appears to me that they already knew that this was erionite, and they were simply confirming that the EDS spectra were consistent with that. And in that case, it's not necessary to print out the chemical composition.
In the case of the particles being studied by Drs. Longo and Rigler, we have no such knowledge. We have no idea and no independent constraints on what mineral it could be or what the composition could be. And, therefore, it is their obligation to produce as much quantitative information as

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possible.
So again, I would need some further study to address specific questions about this paper, but my understanding is that they're simply showing that the SEM images and the EDS analyses are consistent with their existing supposition that this is erionite.
Q. And their existing supposition that this is erionite is based on testing that people have done of the soil in Mexico where they found erionite fibers, right?
A. I don't --
MR. FROST: Objection. Form.
THE WITNESS: I don't know that for a fact. I'd have to take much more time to review this paper.
QUESTIONS BY MR. FINCH:
Q. All right. So Figure 6 has a EDX spectra of Mexican soil with erionite, correct?
A. That's what it says here.
Q. And again, there's no quantitative data printed out in Figure 6 C, correct?

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A. Again --
Q. Of the type -- of the type that is shown in Exhibit 7 {sic} in your report, Figure 7 in your report?
A. There are no chemical analyses printed out here because it would not be appropriate. They already know it's erionite based on, it looks like, independent studies.
Q. Okay. They already know it's erionite based on independent studies.
How do you know that Dr. Longo and Dr. Rigler don't already know that there is tremolite and anthophyllite asbestos in the Vermont talc based on independent studies that other analysts have done?
MR. FROST: Objection to form.
MR. LOCKE: Objection.
MR. CHACHKES: Objection.
THE WITNESS: There is no evidence in Drs. Longo and Rigler's reports, plural, that they have any data that confirm that any of the particles they studied are asbestos.
Perhaps that's a good place to break for lunch.

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MR. CHACHKES: It is lunchtime. It's kind of 12 what? 12:40?
MR. FINCH: Let me have two follow-up questions based on that.
QUESTIONS BY MR. FINCH:
Q. You haven't reviewed anybody's testing of talc from the Windsor mines in Vermont, have you, ma'am?
MR. FROST: Objection.
MR. CHACHKES: Objection.
QUESTIONS BY MR. FINCH:
Q. Other than Longo and Rigler?
A. I was asked --
MR. CHACHKES: Objection.
THE WITNESS: -- to review the methodology of Drs. Longo and Rigler, and that's what I did.
QUESTIONS BY MR. FINCH:
Q. You don't know what Johnson & Johnson documents they have reviewed, they'd given the same kind of information about the potential for tremolite asbestos and anthophyllite asbestos to be in those mines that the authors of the 2016 paper that's Exhibit 15 have about the erionite in Mexico,

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do you?
MR. CHACHKES: Objection.
MR. FROST: Objection.
THE WITNESS: As I said at the outset of this question period, I looked at all the references cited by Drs. Longo and Rigler and read the ones that were available to me. So I do not recall them alluding to any such testing reports.
QUESTIONS BY MR. FINCH:
Q. And if they had, they have that as a source of their basis for knowledge, you don't know about it, right?
MR. CHACHKES: Objection.
THE WITNESS: I can't read the minds of Drs. Longo and Rigler, no.
QUESTIONS BY MR. FINCH:
Q. You can read the trial testimony and the discussion of the Johnson & Johnson tests and documents of Dr. Longo in multiple ovarian cancer and asbestos cases, and you haven't done that, correct?
MR. CHACHKES: Objection.
MR. FROST: Objection.

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THE WITNESS: I have not done that because it would not be relevant to my task, which was to evaluate their methodology.
MR. FINCH: All right. This is a good time to break for lunch.
VIDEOGRAPHER: Okay. Please remove your microphones. The time is 12:37 p.m. Off the record.
(Off the record at 12:37 p.m.)
VIDEOGRAPHER: Okay. We are back on the record. The time is 1:22 p.m.
QUESTIONS BY MR. FINCH:
Q. Good afternoon, Ms. Darby Dyar. We are back on the record after a lunch break.
Did you review any documents over the lunch break?
A. No.
Q. You were talking about, in connection with the erionite paper that I just showed you, the scientists who wrote that paper had information that erionite was a possible mineral in the soil in Mexico,

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correct?
Do you recall that discussion?
A. Let me pull the paper out and take a look at it.
So, yes, what I said was it appears that this is a report based on results from a vehicle repairman who was raised on a farm in the Mexican volcanic belt region.
Q. And what information did the scientists have that led them to suspect that erionite might be in that region of the world?
MR. FROST: Objection.
THE WITNESS: You know, this paper is seven pages long. I'd happy to take the time to read it. But I would need time, to answer that question, to read this paper.
QUESTIONS BY MR. FINCH:
Q. You said before you read the paper that the -- Dr. Gunther and the other scientists who wrote it had some information that erionite was a possible contaminant in the soil in Mexico.

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And I'm just wondering how you came to that conclusion when I just showed you the paper before lunch.
MR. CHACHKES: Objection.
THE WITNESS: Well, I looked at that line that I just read, that the person had epithelial malignant pleural mesothelioma in a vehicle repairman. So -- and it says who was raised on a farm in the Mexican volcanic belt region. So I -- that's where I'm getting that conclusion.
But as I said before, I'd have to read the paper to have -- to have any ability to answer your question in an accurate way.
QUESTIONS BY MR. FINCH:
Q. Okay. Would you agree that talc mines can have differing amounts of accessory minerals in the ore, in the talc ore, in the mine?
MR. CHACHKES: Objection.
THE WITNESS: I honestly don't know anything about talc mines. I do know that rocks that contain talc can

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have a wide variety of mineral assemblages, but I don't know anything about mines specifically.
QUESTIONS BY MR. FINCH:
Q. Okay. Rocks that contain talc can have differing amounts of accessory minerals in the ore that the talc is mined from, correct?
MR. CHACHKES: Objection.
MR. FROST: Objection.
THE WITNESS: Again, I only know in general terms where -- how talc is formed geologically. I know nothing about talc mines, so I can't answer any questions relating to talc occurrences in mines.
QUESTIONS BY MR. FINCH:
Q. Well, would you expect that the owners of the Johnson & Johnson mines in Vermont would have documented their understanding as to what material they were mining out of the ground over the course of the 35 years that the mines were operating?
MR. FROST: Objection.
THE WITNESS: As I said, I

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don't know anything about mine protocols or documentation. I have no knowledge of that, and I'd have to read up on it and research it to give you a good answer.
QUESTIONS BY MR. FINCH:
Q. Okay. You said you reviewed some of Dr. Longo's state court reports, in addition to his three reports in the MDL, correct?
A. Yes. I skimmed them to look for more analytical data, and having found none, I didn't consider them further.
Q. Okay. Did you see that in those reports, or in the disclosures that went with those reports, he had listed certain documents with Johnson & Johnson or Imerys Bates numbers on them that formed part of the basis of his knowledge in the state court cases?
A. No, because as I just said, I only skimmed those documents to look for data that were relevant to my investigation, which was to evaluate the methodology used by them in the Longo and Rigler reports cited in my

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report.
Q. Okay. So to the extent that Dr. Longo, in various state court reports or in disclosures that you've been provided with, lists out Bates labels of Johnson & Johnson documents or Imerys documents, you didn't bother to review those; is that correct?
MR. FROST: Objection.
THE WITNESS: As I said, those documents were reviewed by me only with the goal of looking for further analytical data.
But my goal in this undertaking is to evaluate methodology, and so I did not deem that that was relevant and, therefore, did not pursue the additional references in those reports.
QUESTIONS BY MR. FINCH:
Q. Is it your opinion that the entire universe of minerals that exists on the planet Earth can be found in the Vermont talc mines from which Johnson & Johnson obtained ore for baby powder?

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MR. LOCKE: Objection.
THE WITNESS: I have no knowledge of anything having to do with the geology of -- of the Vermont talc mines. So I would presume that because they are rocks, they contain minerals, but I know nothing about either the geology or the mineralogy of the Vermont talc mines.
QUESTIONS BY MR. FINCH:
Q. Your textbook was -- with Dr. Gunther was written for students, is that correct, graduate-level students?
A. Actually it was written for undergraduate-level students, but we've sold a lot of copies of the book to people that don't do either of those things. We presume; we don't really know.
Q. And the purpose of the book was in part to teach them how to analyze minerals to determine what they are?
A. Yes, that's part of a standard mineralogy curriculum.
Q. Would you agree with me that if you are a geologist who was -- or any

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scientist who was retained to analyze materials that come from a specific mine in a specific part of the world, one reasonable thing to do would be to read information about that geographic mine or that geographic source of the materials so that they have some understanding of what other researchers have found when they have investigated that particular mine?
MR. CHACHKES: Objection.
THE WITNESS: That's a really nebulous, hypothetical question. I was not hired to do that; I was hired to review methodology. So I don't have an opinion on that question because I haven't even thought about it.
QUESTIONS BY MR. FINCH:
Q. Have you ever been -- you have been hired, have you not, to analyze rocks and minerals found in outer space, on Mars or the moon, for example, to try to determine what they are, right?
A. I am funded by both NASA and the National Science Foundation to study

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mineralogy of objects from all over the solar system, yes.
Q. And as part of your background work in -- let's say you're given a grant to study minerals found on the moon.
As part of your work, isn't it correct that you go and review the literature that exists about what other scientists have found in that environment that gives you some background understanding of what you might be looking for?
MR. FROST: Objection.
THE WITNESS: It depends on what I was -- what I was engaged to do or what I proposed to do. If I proposed to do a certain kind of analysis, yes, I would want to know who else had done analyses on that same material.
But in this particular case here, I wasn't hired to do any testing, so I have no opinion on -- no interest in knowing what the rest of the literature says because I'm only evaluating methodology.

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QUESTIONS BY MR. FINCH:
Q. Dr. Longo was hired to test specific products and specific ores where the source of that material was ultimately talc mines in Vermont, Italy or China, correct?
MR. CHACHKES: Objection.
THE WITNESS: All I know is that the materials that are in this -- that I reviewed in preparation of this report came from Asia, Vermont, and I don't remember where else.
QUESTIONS BY MR. FINCH:
Q. Italy?
A. Italy.
Q. And would you agree with me that it would be a reasonable thing for a scientist to do, who had been tasked with the job of analyzing the minerals in a product where the source of the primary ingredient of the product was a mine in a particular part of the world, to read studies that the people who owned the mine had done on the nature of the minerals that they were taking out of the ground?
MR. LOCKE: Objection.

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THE WITNESS: No, I explicitly do not agree.
The only thing that's relevant is the methodology and the data that were produced in the reports and whether or not the methodology is good, which it, of course, is not.
So where the minerals came from is of no concern to whether -- to what the methods were that were used to analyze it. Those two things have nothing to do with each other.
QUESTIONS BY MR. FINCH:
Q. Would you agree with me that if you're doing a bulk analysis of a sample to determine whether or not it has asbestos in it or not, information about the manufacturer of that sample would be important information for Dr. Longo or any scientist to know before testing the material to determine whether and to what extent it had asbestos in it?
MR. FROST: Objection.
THE WITNESS: No, I do not agree. And in fact, I can't even understand why you would want to know

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that.
What you want to know is what's in the material based on the analytical methods that you're using, and that has nothing to do with where the material came.
In fact, knowing where the material came from might bias a judgment, whereas unbiased judgment, which is what we want in science, would probably be most useful.
(Dyar Exhibits 16 and 17 marked for identification.)
QUESTIONS BY MR. FINCH:
Q. Let's mark this as Exhibit 16 and 17.
Okay. I'm putting Exhibit 16 and 17 in front of you and ask if you've ever seen them before.
A. No, Exhibit 16, and no on Exhibit 17.
Q. All right. Turn to page 2 of Exhibit 16.
Did you have the understanding that in 1989 Johnson & Johnson sold the mines

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that it -- in Vermont that it got its talc from to a company called Cyprus?
MR. FROST: Objection.
THE WITNESS: I have no knowledge of that.
QUESTIONS BY MR. FINCH:
Q. And then ultimately, through a series of other transactions, ended up -- the mines are owned by Imerys?
A. I have no knowledge of that.
Q. On page 2 of Exhibit 16, the Cyprus employees who are writing this document write that "the other serious mineralogical contaminant in the talc ores of Vermont is the fibrous variety of the amphibole minerals, tremolite and actinolite, hydrous calcium, iron magnesium silicates, which have been classified as asbestiform minerals by OSHA and EPA. OSHA was suspected to declassify nonfibrous, blocky tremolite on February 29th but not -- has not as yet announced their decision. As a result, all tremolite, the fibrous varieties of all amphiboles and chrysotile asbestos in talc ores, are a source of great concern to all

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talc producers and especially to the marketers of cosmetic products. Cyprus claims that there are no fibers in their cosmetic talc products, and they work rigorously to ensure this. However, a recent paper published by Rutgers University worker Alice Blount suggests the presence of fiber in several cosmetic talcs, some of which might have been from Cyprus West Windsor, which is a source of great concern to Cyprus management and potentially to their principal customer, Johnson & Johnson. Talc de Luzenac personnel are well aware of the situation, and Phillipe Moreau is currently quietly working to identify the reality and the magnitude of the problem.

"Vermont talcs are derived from altered serpentine, a natural host for asbestiform minerals. There is certainly visible tremolite and actinolite in specific zones of Vermont deposits. Fibrous tremolite was identified by the writer in exposures and cores at the East Argonaut and Black Bear mine. Cyprus staff report tremolite from the Hammondsville and Clifton deposits."

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MR. CHACHKES: Past. You missed --

MR. FINCH: Past tremolite from the Hammondsville and Clifton deposits.

QUESTIONS BY MR. FINCH:

Q. Do you see that?

A. I see that that's what the document says, yes.

Q. Okay. And you have no knowledge one way or another to suggest that the authors of this memorandum are wrong in their conclusions, correct?

MR. CHACHKES: Objection.

MR. LOCKE: Objection.

THE WITNESS: I do not have enough information about this document to render an opinion.

I see that it's an interoffice correspondence. It talks about mines in Vermont, but Vermont's a big state. These deposits are presumably aerially very large. I don't know if these deposits were used for talc.

So there's just not enough

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information in this document for me to be able to say anything.

QUESTIONS BY MR. FINCH:

Q. Okay. So you certainly can't opine that this information contained in Exhibit 16 is incorrect, can you, ma'am?

MR. FROST: Objection.

MR. CHACHKES: Objection.

THE WITNESS: Indeed, I can't opine if it's correct either. I have no opinion.

QUESTIONS BY MR. FINCH:

Q. Okay.

A. Because there is insufficient context and information about this document.

For example, it says tremolite, but there's no indication of really what kind of tremolite it is. It confuses the definition of fibers.

I would say there are a lot of issues with this document that I would want to know more about, so I can't really comment about this document.

Q. Okay. Exhibit 17, do you have that document?

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A. I do.

Q. This is analysis of fibrous material from Argonaut waste rock?

A. Yes, I see that.

Q. Dated May 23, 2002?

A. Yes. That's what it says.

Q. Do you know who Julie Pier is?

A. No.

Q. You don't know that she's a scientist for Luzenac America at the time this memorandum was written?

MR. FROST: Objection.

THE WITNESS: I've never heard of either Julie Pier or Luzenac.

QUESTIONS BY MR. FINCH:

Q. All right. On the second page there is an SEM image and an EDS chemical analysis of waste rock from the Argonaut mine.

Do you see that?

A. Yes.

Q. All right. Do you agree with me that the pictograph at the top, the material looks like fibrous material and not fragments?

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A. It's almost impossible to judge that from a two-dimensional image, so I don't really have any opinion on that. I don't have an opinion.

I'd like to be able to measure the population and do an analysis on it that way to render an opinion.

Q. Would you agree with me that a scientist using a scanning electron microscope can, by moving the plates around, look at the structure that he or she is viewing in three dimensions and make a determination whether morphologically and visually it looks more like a fiber or a bundle of fibers or a cleavage fragment?

MR. FROST: Objection.

THE WITNESS: No, I do not agree with that statement. In fact, the amount of tilt on the stage is very small. There's no way you can get a three-dimensional view of something.

Only with a special kind of polarizing light microscope can you actually do a three-dimensional

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assessment in that manner.

QUESTIONS BY MR. FINCH:

Q. Do you see also that there's an EDS chemical analysis below it?

A. I do.

Q. And the -- Dr. Pier concludes, based on that, that the chemical analysis of the material is consistent with tremolite?

MR. CHACHKES: Objection.

THE WITNESS: I see that that's what this document concludes, yes.

QUESTIONS BY MR. FINCH:

Q. And the SEM, EDS analysis on the second page of Exhibit 17 contains a conclusion that the chemical composition of the material is consistent with tremolite, correct?

A. It says, "The chemical analysis of the material above is consistent with tremolite." Yes, that's what it says.

Q. And it doesn't have any of the quantitative data found at the bottom of Figure 7 in your report, correct?

A. That's correct. It looks to me like another example of bad science.

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Q. This is science being done for commercial purposes, correct?

MR. FROST: Objection.

THE WITNESS: As I've stated, I have no idea what Luzenac is.

QUESTIONS BY MR. FINCH:

Q. This was science being done not for courtroom purposes?

A. I have no idea what the purpose of this document is. I don't know anything about the context. And it appears that there is additional information that is not included in the two pages that I've been given, so it's hard to comment on this. I can't even tell if this is the entire memo.

Q. Can you opine one way or another about whether tremolite exists in Vermont talc mines?

MR. CHACHKES: Objection.

THE WITNESS: No, I cannot. I saw no evidence in any of the Dr. Longo and Rigler reports that I examined that supported a conclusion of asbestos being present, and that's the only data that I'm familiar with.

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Those are the only data I'm familiar with.

QUESTIONS BY MR. FINCH:

Q. Can anthophyllite have varying amounts of iron?

A. Yes.

Q. We haven't talked about another way to analyze the chemical composition of materials, X-ray diffraction or XRD.

Are you familiar with that?

A. Certainly. There's a chapter if my book, and I teach that routinely.

Q. Would you agree with me that what X-ray diffraction does, it allows you to -- well, you tell me what X-ray diffraction does, XRD.

A. X-ray diffraction is a superset of what we've been talking about, SAED. It uses diffraction of atoms in layers in a mineral structure to indicate diagnostic properties such as the spacing between the atoms in the structure.

Q. Is X-ray diffraction a sensitive-enough tool to find asbestos contamination in material if it's less than

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0.1 percent by weight of the material?
MR. FROST: Objection.
THE WITNESS: So I believe if you look at the ISO 22262-1, it explains that in fact it is difficult to measure abundances of small materials at those levels with X-ray diffraction.
QUESTIONS BY MR. FINCH:
Q. Would X-ray diffraction allow you to determine whether or not there is fibrous talc in a sample of talc that you were testing?
A. Absolutely not.
MR. LOCKE: Objection.
THE WITNESS: Because X-ray diffraction uses the arrangement of atoms in the crystal structure, which at best only tells you which mineral species it is. But X-ray diffraction cannot determine anything about the morphology of particular particles.
QUESTIONS BY MR. FINCH:
Q. Would you agree that talc can be fibrous?

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A. I have no knowledge of that because I haven't studied that.
Q. But whether talc is -- can be fibrous or not, you wouldn't -- X-ray diffraction would not be able to tell you whether there was fibrous talc in a sample of talc, correct?
A. Correct. X-ray diffraction cannot determine the morphology of a particle. Only confirm the crystal structure.
Q. You just used the word "morphology" in a sentence.
Can you define how you used morphology in that sentence?
A. I meant the shape, aspect ratio. It's a...
Q. So morphology can mean shape and aspect ratio?
A. Well, I was saying as -- for example, as evidenced by aspect ratio, is what I meant to say.
Q. Okay. As evidenced by aspect ratio?
A. Correct.

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Q. And aspect ratio just is the ratio of length to width; is that correct?
A. That's correct.
But it's possible to have morphologies that have nothing to do with dimensions.
Q. How so?
A. For example, minerals form as -- in rose shapes with petals, so that's a specific morphology.
Q. Would you agree with me that minerals can form in bundles?
A. Bundles is not a term we generally use to identify minerals. For example, I don't believe we even discuss the term "bundle" in the chapter of our book where we talk about the physical characteristics of minerals.
On the other hand, in my report I show a photograph of a -- of a -- excuse me, of a bundle, so indeed I'm aware that some minerals can form as bundles.
Q. Do you agree with me that asbestos fibers can form as bundles?
A. Well, given that there's a

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picture of a -- here we go. It's Figure 23 B. It's an image of a tremolite bundle of asbestiform particles from a paper by Harper, et al.
So, yes, given that this image exists, and to the extent that Harper asserts that they can form as bundles, then, yes, indeed, tremolite can form as an asbestiform bundle.
Q. And can anthophyllite form as an asbestiform bundle?
A. I have personally not seen either an image or a -- with my own eyes, an anthophyllite bundle, so I really can't answer that question either way.
Q. So morphology refers to the shape as measured by aspect ratio and --
A. As measured, for example, by --
Q. As measured, for example, by the aspect ratio and the nature in which the material can be found, whether it's rose-petal-shaped or a bundle or a fragment or something else, right?
A. Correct.
Q. And those are -- the way you

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would analyze that in a laboratory is you would take a photomicrograph of it using either a PLM or a electron microscope, scanning or transmission, and take measurements of the structure that you're observing to determine what its aspect ratio is, how thick it is, how long it is, and what it looks like visually, like exhibit -- excuse me, Figure 23 C that you referred me to before.

MR. CHACHKES: Objection.

QUESTIONS BY MR. FINCH:

Q. Correct?

A. I referred you to 23 B before.

Q. Excuse me, 23 B as in boy.

A. So I got to look at your question.

It -- actually, can you restate the question as a question?

Q. Sure.

Morphology, I'm trying to get the universe of the stuff that goes into the analysis of morphology.

It is the shape as, for example, measured by aspect ratio, the size,

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the appearance, and the form in which it is found, as exampled by either a bundle or a rose petal shape.

Are those all the aspects of morphology as it relates to asbestos minerals?

MR. FROST: Objection.

THE WITNESS: The only aspect of morphology that applies -- that is relevant to this identification of asbestiform minerals is whether or not the population of shapes expressed as width versus length or aspect ratio belongs to the population of asbestiform or non-asbestiform minerals. That is the only aspect of morphology that's relevant to this particular inquiry.

QUESTIONS BY MR. FINCH:

Q. Okay. And that population of shapes, that is a statistical analysis you do if you have enough structures to analyze for purposes of aspect ratio, correct?

A. Correct. You cannot make a firm diagnosis on the basis of an individual

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image or individual crystal.

Q. Okay. So if you have an individual image that is 10 microns long, you can't make a conclusive diagnosis or determination as to whether or not based on morphology it is asbestiform or non-asbestiform, correct?

MR. FROST: Objection.

THE WITNESS: You cannot determine anything from an individual image. You need a population to be able to make a determination.

QUESTIONS BY MR. FINCH:

Q. Okay. And how many fibers consist of a population or images, structures?

A. Statistically, that's a difficult answer -- that's a difficult question to answer. It would depend on the context and the problem at hand.

Q. Is there any generally accepted standard that you could point me to that says in order to do a statistical analysis of a population you need a minimum of X structures or fibers to analyze?

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A. I would want to go back and look at some of the papers that I cited where we talk about looking at populations. For example, the R-93 document talks about populations. One of these ISO documents talks about populations. But I do not recall specifically any of them having a number of samples that you'd have to analyze.

We talk about this in my statistics book. The number of samples that you need for any given scenario is extremely variable.

Q. So sitting here right now, which is my one chance to take your deposition before the Daubert hearing, you don't know of any generally accepted or relied upon standard which has a minimum number of fibers or structures you need to analyze in order to analyze the aspect ratios to determine whether it's asbestiform or non-asbestiform?

MR. FROST: Objection.

MR. LOCKE: Objection.

THE WITNESS: I would say you need enough fibers to create a

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distribution with an acceptable standard deviation on the mean.
QUESTIONS BY MR. FINCH:
Q. Is 100 fibers or structures sufficient to do that?
A. I think that's -- that's subjective and it depends -- you know, it depends on the particular profile of the population. And it also depends on the confidence with which you want to be able to state your opinions or your conclusions.
Q. All right. At page 18, footnote 34.
A. Page 18 of my report?
Q. Yes, page 18, footnote 34.
A. Uh-huh.
Q. You say, "The EDS results in the Longo, Rigler MDL reports labeled as tremolite may very well be consistent with minerals other than diopside."
Do you know if diopside has ever been found in any of the mines in Vermont that Johnson & Johnson obtained talc from?
A. No, I don't know anything about

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the mineral assemblages present anywhere in Vermont.
Q. You go on to say, "Dr. Longo and Rigler might have never produced their quantitative data and, accordingly, this analysis cannot be completed, drop footnote 34.
"For example, these may include at least monticellite, bredigite, merwinite and rondorfite, which are other minerals that contain only silicone, magnesium and calcium."
A. That's what I say.
Q. All right. Do you know if -- where in the world monticellite is found?
A. Actually, monticellite is found in New York. I've collected it in the Adirondacks just across the river from Vermont.
Q. Do you know if it's ever been found in any of the mines in Vermont that Johnson & Johnson obtained its talc from?
MR. CHACHKES: Objection.
THE WITNESS: I know nothing about the mineralogy of the Vermont

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talc mines.
QUESTIONS BY MR. FINCH:
Q. Do you know where in the world bredigite is found?
A. No.
Q. Merwinite?
A. No.
Q. Rondorfite?
A. No.
Q. You don't know if any of those minerals were ever found in any analysis anyone's ever done of talc from Vermont used by Johnson & Johnson, correct?
A. I believe I've made it clear that I know nothing about the mineralogy of any of the rocks in Vermont.
Q. Or that would go for Italy and China as well? You know nothing about the mineralogy of the talc mines Johnson & Johnson sourced its talc from Italy or China?
A. That's correct.
May I add that although those minerals are very rare, I continue in my footnote to say many more common minerals would be included in this list if iron and

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sodium were allowed.
So I specifically created this example to be simple, but, in fact, in nature there would be many, many minerals that would be easily confused with tremolite on the basis of an EDS analysis.
Q. All right. We were talking about morphology a little while ago.
That's one way -- one analysis that a scientist does to determine whether or not material he or she is analyzing is asbestos or not, right? It's one of the pieces of the puzzle?
A. So, indeed, the criterion to be lengthwise separable into flexible fibers with high tensile strength and flexibility is the definition of asbestos, then, yes, the assessment of whether something is that sort of fiber is relevant, yes.
Q. And one of the analyses that goes into that is analysis of aspect ratios, correct?
A. Aspect ratios are one way of making that assessment, yes.
Q. Okay. And another analysis

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that a scientist can and should do to determine whether or not the material he is analyzing is asbestos or not is an analysis of its chemical composition, correct?

A. So the definition of asbestos includes chemical composition, crystal structure and lengthwise separable into flexible fibers with high tensile strength.

So to the extent that chemical composition is part of identifying a specific mineral species, then, yes, it's relevant.

Q. Amosite is one of the well-accepted amphibole minerals that can be asbestiform?

A. That is one of the six minerals that's listed in the many lists in this document, yes.

Q. Do you know whether amosite can split both horizontally as well as longitudinally?

MR. FROST: Objection.

THE WITNESS: I have no explicit knowledge of amosite. There was no mention of amosite in the Longo and Rigler documents that I was asked

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to review, and, therefore, I have no opinion on that because I have not investigated that question.

QUESTIONS BY MR. FINCH:

Q. The way one determines the chemical composition of a fiber or structure that one expects to potentially be asbestos is using EDS, EDXA, correct?

A. So as I explained in my report, EDS and EDXA are the only analytical -- geo-analytical techniques that are high enough in resolution to be able to say anything about the chemical composition of a very tiny particle.

Q. And that is a qualitative analysis that is semi-quantitative at best, correct?

A. Correct.

Q. A third step that a scientist should undertake to determine whether or not a particle or structure that he or she is analyzing is asbestos is to analyze its crystalline structure, correct?

A. Using a technique such as SAED, yes.

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Q. And SAED is performed with either a transmission electron microscope or a SEM microscope?

A. Generally, yes.

Q. And the analyst has the structure or bundle on the grid, or on multiple grids, and is able to rotate it and look at the SAED -- look at the crystalline structure by SAED from different angles or viewpoints, correct?

A. Sort of.

Q. What's a goniometer?

A. So a goniometer is something that allows you to swivel something in three-dimensional space. But on a TEM, the space constraints are such that you can only swivel it a very small amount.

Q. Does polarized light microscopy allow you to determine whether or not a structure or a fiber is asbestos or not?

A. PLM allows you to determine the refractive index of a material, and it allows you to say something about the dimensions of an individual particle. But it tells you nothing about the population distribution

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and, therefore, couldn't tell you anything about whether or not it was asbestiform or non-asbestiform.

Q. But if you have a sample of material and you combine all four different analysis - morphology, the chemical composition analysis using EDS, EDXA, the crystal structure analysis using SAED, and a polarized light microscope analysis of the material, the same -- the sample - would that give you a high level of confidence that what you were looking at was asbestos if it was consistent with the regulated asbestos materials as measured by morphology, chemical composition, crystal structure and refractive index?

MR. CHACHKES: Objection.

THE WITNESS: Well, that's quite a mouthful of a sentence.

Boy. If done correctly. But, of course, the methodology used in the Longo, Rigler report was not done correctly.

For example, you say SAED. Well, a single SAED analysis is not

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enough to identify a mineral. So if you only had one SAED, then you couldn't identify asbestos, et cetera, et cetera.

If you only had one measurement of the dimensions of the particle, you wouldn't know anything about the population from which it was drawn and, therefore, you could not determine if it came -- if it was asbestos.

So that's a general -- generalized question that is impossible to answer. But I can certainly say that with the individual measurements -- or with the methods used in the -- used by Drs. Longo and Rigler, no, you cannot determine if something is asbestos.

Moreover, I will also say that each of those techniques perhaps identifies maybe 250 to 500 different possible minerals -- I'm just making those numbers up -- and they're the same 250 to 500 minerals because they

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all have very similar compositions, crystal structures, et cetera, et cetera.

So this methodology is fundamentally flawed.

QUESTIONS BY MR. FINCH:

Q. Are you saying the -- let me focus on the SAED.

What's the basis for your statement in your report at page 29 and 40 that --

A. You mean 29 and 30?

Q. 29 and 40. You say it in two different places.

A. Oh.

Q. You cite to Yamate for the proposition that SAED requires at least two zone axes in order to make a determination of the crystalline structure.

A. Yes, that's correct.

Q. What's the basis for that statement?

A. One SAED pattern only tells you two dimensions of what is a three-dimensional crystal structure lattice. As it happens,

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having only two dimensions is not diagnostic, which is the point of the data I present in this report to show that there are many, many minerals that satisfy the D spacing criteria that Dr. Longo uses.

Q. All right. The D spacing is the space -- the distance between the atoms, correct?

A. Distance between layers of atoms, yes.

Q. And the zone axis measurement is the measurement of the angles?

A. The zone axis measurement just refers to the way the crystal was positioned at the time the X-ray pattern was collected relative to the crystal structure itself.

Q. And you -- and you say that the Yamate 3 methodology for confirming the presence of asbestos in talc requires two SAED zone axis determination and an EDS analysis, correct?

A. That's what the Yamate statement says. And if you'd like, we can take a look at that together.

Q. Well, we'll get to there in a

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minute.

Other than Yamate, 1984, can you point me to any generally recognized standard or peer-reviewed literature that says that you have to have two SAED zone axis determinations for every particle that one is analyzing using SAED?

A. So I would imagine that every mineralogy book ever written about crystallography explains that minerals are three-dimensional structures, and it's always necessary to know all three directions in order to identify a mineral.

Books that come to mind include probably the Hurlbut and Klein textbook that you already have, Bloss' optical crystallography book, certainly my book.

And many other sources would tell you that just because a mineral has one particular dimension, which is basically what Dr. Longo provides in the diffraction verification document, no conclusions can be drawn regarding identification.

Q. With respect to asbestos specifically, can you identify anything

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besides Yamate that states that you need two SAED zone axis determinations in order to -- and an EDS analysis in order to make a determination that a material is asbestos?

MR. FROST: Objection.

THE WITNESS: I'm sure I could find some citations. It's such a common, obvious thing that I don't think anyone would write a peer-reviewed paper to even say that.

QUESTIONS BY MR. FINCH:

Q. You haven't listed anything other than Yamate in your report; is that correct?

A. To support this particular point, no, because it's common knowledge among crystallographers.

Q. All right. You have Yamate. I think it's Exhibit --

A. 7.

Q. 7.

You were quoting from page 44?

A. Uh-huh.

Q. "The protocol states that the identification requires two SAED zone axis

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determinations and an EDS analysis."

You're referring to the -- I'm on page 41. You're referring to the Yamate protocol, right?

A. Oh, wait a minute. Are we talking about my report now?

Q. I'm looking at your report, page 41, and it says, "The protocol," referring to Yamate, "states that identification requires two SAED zone axis determinations."

A. Yes, that's what it says.

Q. Okay. And where does it say that in Yamate?

A. Oh, let's take a look here.

On page 44 it says, "The level 3 analytical procedure consists of locating the selected fibers," blah-blah-blah, "obtaining and according two zone axis SAED patterns from each selected fiber, and obtaining, recording and photographing representative EDS spectra from the subject fiber."

Q. Okay. Does the Yamate criteria require that SAED analysis from two different

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near exact zone orientations be done for every structure that one is looking at?

A. That's what it says.

Q. Could you turn to the next page?

A. It says "from each selected fiber."

Q. Turn to the next page in Yamate.

A. (Witness complies.)

Q. Under point 5 it says, "It is recommended that approximately 20 percent, at least 10 percent of the fibers examined in level 2 analysis, be selected for level 3 SAD -- SAED analysis. Fibers which would be classified as amphiboles are ambiguous in level 2 analysis should be more often included for level 3 analysis as compared to those fibers which could readily be identified as not asbestos."

Do you see that?

A. I see that.

So let's take this back to what's actually in the Longo, Rigler reports.

So in point of fact, there are

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no individual fibers for which two SAED patterns are given. And in fact, only after the fact were any diffraction verification documents given, and I don't believe that they represent even 20 percent of the particles identified by Drs. Longo and Rigler. So their methodology is flawed on many counts relating to this.

Q. Isn't it true that the SAED diffraction verification documents that Longo and Rigler provided consist of more than 10 percent of the total number of structures they analyzed?

A. I believe they only looked at six out of the 70-odd samples that they studied, so six out of 70-odd is not quite 10 percent. I don't have the exact numbers in my head.

Q. ISO 22262-1 is a publication that you at least cite to and rely on in your discussion of Dr. Rigler and Dr. Longo's work, correct?

MR. FROST: Objection.

THE WITNESS: I certainly point out where their methodology is

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consistent and inconsistent with what's in this report, yes.
QUESTIONS BY MR. FINCH:
Q. Could you turn to page 64 of what's been marked as Exhibit 4, ISO 22262-1?
A. Section F 3?
Q. Yes.
What is it talking about in section F 3?
A. Electron diffraction.
Q. Is that another name for SAED?
A. In this context, yes.
Q. Okay. One, two, three, four, five paragraphs down --
A. Uh-huh.
Q. -- ISO 22262-1 states, "ED," referring to electron diffraction patterns, "can be particularly useful for differentiating fibrous talc from anthophyllite asbestos, both of which have similar EDXA spectra."
First of all, do you agree that fibrous talc and anthophyllite asbestos have similar EDXA spectra?
A. I agree that talc and

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anthophyllite have similar EDS spectra because, of course, that's all you can say about those methods. They only look at chemistry. So all I can say is that chemically, talc and anthophyllite can be quite similar.
Q. Then going on to, "Electron diffraction of talc produces a pseudo hexagonal pattern that does not change as the fiber is tilted using the goniometer. Anthophyllite asbestos, on the other hand, produces assorted spots appearing and disappearing along layer lines as the fiber is tilted using the goniometer."
That refers to the analyst looking at the sample in the transmission electron microscope and tilting it, correct?
A. That's what it refers to, yes.
Q. All right. The next two sentences deal with chrysotile, so I'm going to skip those.
"Analysis of laboratory samples seldom requires zone axis measurements. However, if a zone axis ED analysis is to be attempted on the fiber, the sample should be

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amounted in the appropriate holder" --
MR. CHACHKES: Mounted.
QUESTIONS BY MR. FINCH:
Q. -- "mounted in the appropriate holder."
And then it goes on to describe the complete rotation of the specimen grid and the tilting of the grid about a single axis.
Do you see that?
A. Yes.
Q. And it instructs the analyst to tilt the fiber until an ED pattern appears, which is a symmetrical, two-dimensional -- which is a symmet -- two words, a, space, symmetrical, two-dimensional array of spots. The recognition of zone axis alignment conditions require some experience on the part of the operator.
Do you agree with that?
A. Yes. Although we teach students to do that.
Q. And you agree with me that what's going on here is the analyst is tilting the structure around in realtime,

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looking at it through the transmission electron microscope to look -- to see whether or not when he or she adjusts the goniometer that the -- whether or not the hexagonal pattern changes or not?
A. Sort of.
What's going on is that you're trying to tilt the sample so that rows of atoms in the sample are perpendicular to the beam of electrons. That's what you're doing.
And that satisfies the diffraction condition and, therefore, gives a pattern of spots.
Q. All right. On page 65 --
A. Uh-huh.
Q. -- the standard states, "If the results obtained from one ED pattern do not resolve any ambiguity in the identification of a fiber, a second ED pattern obtained at a different orientation of the fiber can be examined, and the observed tilt angle between the two orientations can be compared with the theoretical angle calculated from the suspected crystal structure."
Do you see that?

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A. Actually, I don't see where that is, but --
Q. Page 65.
A. Yeah, I'm looking at it.
Q. Bottom paragraph.
A. Oh, at the bottom. Yes. Okay.
Q. All right.
A. Where it's talking about using a computer program to do this, yes.
Q. What it says is, "If the results obtained from one ED pattern do not resolve any ambiguity in the identification of a fiber, a second ED pattern obtained at a different orientation of the fiber can be examined."
Would you agree with me that "can" does not say "shall" or "must"?
A. I agree with you that it says "can," but I believe you're proving the point I made in my report, which is that crystal structures are inherently three-dimensional, and you cannot identify a specific mineral species on the basis of only one orientation.
Q. But how do you -- what's -- what is the basis for your conclusion that

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the analysts that were looking at the crystalline structure in realtime using SEM in Dr. Longo's lab were not turning the goniometer to look at it from multiple perspectives?
Do you have any basis for concluding that they weren't doing that?
A. My basis for concluding that is that they only include one image for each crystal. Therefore, there is no evidence in any of their reports that they did multiple zone axis measurements.
Q. So what you're saying is because there's not more than one image, that means that they didn't look at it from two different angles, as ISO 22262-1 discusses at page 64?
A. Precisely. And that is the point I make in my report, that they do not look at more than one zone axis on any individual crystal.
Q. Well, you're just assuming that, aren't you? They just -- they didn't take a picture of a different zone axis.
But wouldn't you agree with me

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that ISO 22262-1 at page 64 says that at least when you're examining anthophyllite asbestos versus talc, it becomes apparent by tilting the goniometer which is which because the image does not change if it's talc, if the fiber is tilted?
MR. LOCKE: Objection.
THE WITNESS: So let's decompose that question a little bit.
First of all, it is true that at specific orientations the diffraction patterns of talc and anthophyllite can look quite similar.
It is also true that if you tilt the stage, you may not see the same pattern of spots for talc and anthophyllite.
But it all goes back to the point I make in my report, which is that if you only have one of these patterns, it doesn't matter how hard you work to get it, one pattern is not enough to identify a three-dimensional structure, because one pattern can only physically tell you about two

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dimensions.
MR. CHACHKES: And by the way, we've been going a little over an hour, if you reach a natural breaking point.
MR. FINCH: Yeah, this is a good breaking point.
MR. CHACHKES: Thank you.
VIDEOGRAPHER: Okay. The time is 2:24 p.m. Off the record.
(Off the record at 2:24 p.m.)
VIDEOGRAPHER: Okay. We are back on the record. The time is 2:46 p.m.
QUESTIONS BY MR. FINCH:
Q. Good afternoon, Professor Darby Dyar. We're back on the record after a short break.
On page 32 of your expert witness report, you write that "The SAED patterns are labeled with mineral species names using only visual inspections based on operator experience, methodology for which the Longo, Rigler MDL report cite no support. This practice may be able to distinguish

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among species for materials that are already known to contain asbestos, but it may fail in the applications where the spectrum of possible mineralogy is broad."

That's what you write, correct?

A. That's what I write.

Q. What is the basis for your statement that the spectrum of possible mineralogy is broad in the talc mines in Vermont, in Italy, from which Johnson & Johnson obtained its talc?

MR. CHACHKES: Objection.

THE WITNESS: So because I know nothing about the mineralogy in those localities, all I can say is this general statement, which is that looking at an SAED pattern, which is what Longo and Rigler and their associates admittedly do in their deposition, makes it difficult to distinguish mineral species in applications where the spectrum of possible mineralogy is broad.

QUESTIONS BY MR. FINCH:

Q. What about in the -- in the

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spectrum where the possible mineralogy is not broad, as in the case of a Vermont talc mine where a handful of accessory minerals have been identified and that's it?

MR. CHACHKES: Objection.

MR. LOCKE: Objection.

THE WITNESS: Well, I don't know anything about the mineralogy of Vermont talc mines, and so I can't say that there's any independent constraints because I don't know that that is the case.

QUESTIONS BY MR. FINCH:

Q. Okay. So you do say that "This practice, i.e., analyzing SAED patterns based on operator experience, may be able to distinguish among species for materials that are already known to contain asbestos."

So presumably you agree that if the operators already know based on some source that asbestos is among the possible materials in the mix of the sample they're looking for, using SAED to label mineral species with names using visual inspection may be able to distinguish among the

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different species, correct?

MR. CHACHKES: Objection.

THE WITNESS: I do use the word "may," and I would say that if you handed me a clump of asbestos and asked me to determine which of the six mineral species it was, I might be able to do -- to use SAED to identify which of the six it was, which is why I deliberately used the word "may" fail.

QUESTIONS BY MR. FINCH:

Q. Am I correct that you have no basis for your conclusion that the spectrum of possible mineralogy in the Vermont source talc used by Johnson & Johnson -- strike that.

Am I correct that you have no basis for your statement in your report that the spectrum of possible mineralogy is broad when it comes to the sources of talc used by Johnson & Johnson?

MR. CHACHKES: Objection.

THE WITNESS: I stand by my statement because, for example, there

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are more than a hundred amphibole minerals. It would be very difficult to distinguish them by SAED.

And as far as I'm aware, I know nothing about the mineralogy of talc mines from which these particular samples that Drs. Longo and Rigler tested. So to me, the spectrum of possible mineralogy is quite broad.

QUESTIONS BY MR. FINCH:

Q. Of those hundred amphibole minerals, how many of them have the same chemical signature as anthophyllite or tremolite and an SAED diffraction pattern that is consistent with asbestos and morphology that has structures which have aspect ratios on average greater than 7 to 1 and that on PLM are determined to be consistent with asbestos?

How many of the hundred amphibole minerals you just talked about meet all those criteria?

MR. CHACHKES: Objection.

THE WITNESS: Wow, that's another omnibus question, so let's

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break that down a little bit.
So chemically, any of the amphibole minerals that are either magnesium, iron and calcium-bearing or just magnesium and iron-bearing would all be indistinguishable by EDS.
If you had one SAED pattern, which most of the data in the diffraction verification document of Dr. Longo's have, they only show one particular orientation that is common to, as we noted in my document, 25 percent of all minerals in the database from our book.
So let's see. What else did you ask?
Let's see. And then morphology, "has structures which have aspect ratios" -- so we haven't even really talked about counting criteria, which is really what you're -- what you're specifying here, 7 to 1. I'm not sure where that number is coming from.
And then when you say "on PLM

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are determined to be consistent with asbestos," again, on PLM you can tell something about morphology because you can measure the dimensions of the grain, and if you use an array of refracted index oils, you can tell something about composition with PLM.
So those are answers to your individual question, and I think it's too vague to try to give a straight answer to your original question as posed.
QUESTIONS BY MR. FINCH:
Q. So sitting here today, you can't give me a number as to how many of the hundred amphiboles that exist would meet all those criteria?
MR. LOCKE: Objection.
MR. FROST: Objection.
THE WITNESS: I would say, for example, that all of the 100 amphibole minerals would meet the SAED one zone axis angles -- or values that are in the diffraction verification documents because they're all amphiboles.

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MR. FINCH: Objection. Move to strike.
QUESTIONS BY MR. FINCH:
Q. My question was: How many, sitting here today, can you tell me would meet all four of the criteria that I just laid out?
MR. LOCKE: Objection.
MR. CHACHKES: Objection.
THE WITNESS: So your criteria were simply just names of techniques. They weren't specific about the names and techniques.
So if you want to tell me what it is about SAED and what it is about PLM and what it is about morphology, et cetera, et cetera, for each of those, then I could probably answer your question. I'd be happy to.
QUESTIONS BY MR. FINCH:
Q. Do you know as you sit here today how many different minerals have been identified in Vermont-sourced talc or Italian-sourced talc that went into Johnson's baby powder?

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A. I have no knowledge of the mineralogy of those deposits or, in fact, any talc deposits.
Q. So it could be three minerals, it could be five minerals, it could be ten minerals; you have no knowledge, correct?
MR. CHACHKES: Objection.
MR. LOCKE: Objection.
THE WITNESS: Correct. I believe we've established that I don't know anything about the mineralogy of Vermont or any other talc deposits, aside from the fact that they contain talc.
QUESTIONS BY MR. FINCH:
Q. Have you ever heard of McCrone Laboratories or Walter McCrone Associates?
A. Yes.
Q. Do you regard them as a well-respected laboratory for the purposes of analyzing materials to determine whether or not they contain asbestos or other contaminants?
A. I don't know anything about that aspect of what they do. I'm only

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familiar with the fact that they teach classes in optical microscopy.
Q. And they teach classes in how to use a microscope to identify materials, correct?
A. They teach classes in how to do fundamental measurements on a microscope, yes.
Q. Have you ever attended a class taught by Walter McCrone and Associates or McCrone?
A. I teach my own classes on optical microscopy, so, no, I have no need and, therefore, have never attended a class taught by McCrone or anyone having to do with McCrone.
Q. Have you ever heard any significant criticisms of their laboratories in your field?
A. McCrone is not an academic laboratory. It's not something that research scientists do. Optical microscopy is generally in the toolkit of mineralogy researchers, and so there would no need to use any laboratory. And, therefore, I barely

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know of McCrone.
Q. Oh, so you haven't -- as you sit here today, there's not any criticisms you have or you can think of of McCrone Associates?
A. I don't have enough information to have an opinion.
(Dyar Exhibits 18, 19 and 20 marked for identification.)
QUESTIONS BY MR. FINCH:
Q. All right. I've marked what's been Exhibits 20 --
MR. CHACHKES: 18.
QUESTIONS BY MR. FINCH:
Q. -- 18 and 19.
MR. CHACHKES: Yeah.
QUESTIONS BY MR. FINCH:
Q. Yeah. 20 is a May 24, 1976 document; is that right?
A. Oh, wait. 20 you want to go to first?
Q. Yes.
A. Yes, it says May 24th.
Q. Okay. And 19, which one is 19?
A. 19 is July 1, 1975.

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Q. And 18 is?
A. November 5th.
Q. All right. I want to do them 20 -- I'm going to do them in reverse chronological order, going backward in time, so starting with Exhibit 20.
Do you have that?
A. I do.
Q. This is a May 24, 1976 letter to Walter McCrone Associates from Roger Miller, who was the president of Windsor Minerals.
Do you see that?
A. That's what it looks like, yes.
Q. Do you have any understanding of who Roger Miller is or what Windsor Minerals is?
A. Never heard of him.
Q. All right. If I were to represent to you that Windsor Minerals was a Johnson & Johnson subsidiary that owned the mines from which it mined talc for cosmetic talc, do you have anything to dispute that statement?
MR. CHACHKES: Objection.

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THE WITNESS: I can neither affirm nor dispute that statement.
QUESTIONS BY MR. FINCH:
Q. All right. Exhibit 20 states that "The samples which are relevant to the production and sale of cosmetic talc in the US and Canadian markets are those bearing the letters HC as part of their prefix. The dates included in the identifier are the dates on which the material was processed."
Do you see that?
A. You read that correctly, yes.
Q. Okay. So this is the president of Windsor Minerals writing to the people at McCrone Associates what the terminology in the letter means, what HC means, correct?
A. That's what it appears. The letter's not signed.
Q. Back in the 1970s, wasn't it a common practice when people wrote letters that there be a carbon copy and sometimes the -- there wasn't -- the Xerox machine was not as ubiquitous as it is now, and you wouldn't always have the signed copy in the file?

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MR. CHACHKES: Objection.
THE WITNESS: It's perfectly easy to sign a carbon copy.
QUESTIONS BY MR. FINCH:
Q. Be that as it may, Windsor Minerals -- you see this is -- this is a document produced from the files of Johnson & Johnson at the bottom?
MR. FROST: Objection.
QUESTIONS BY MR. FINCH:
Q. J&J talc?
A. I have -- I have no knowledge of that, other than your assertion and this cryptic notation which looks like it was added after the fact.
Q. Turning now to Exhibit 18, and keep Exhibit 20 handy.
"This letter will supplement our report of 1 July 1975 on a series of talc ore samples which we have analyzed for you. Table 1 shows the actual fiber counts and the approximate equivalent concentration in parts per million of amphibole particles which we found in these samples. Some of them seem rather high. Most of these come in bundles

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of one, two or three fibers, anything from two to five amphiboles in a bundle."
And it's reporting on the results from McCrone to the Windsor Mineral Company, correct?
A. Apparently.
Q. All right. And on Table 1 on the second page of the document, the back page, there is a column labeled "Fibers of Asbestos"?
A. That's what it says.
Q. And then it -- by cross-referencing the tabs, you can take the sample numbers and if it's -- see whether it's HC or GI or WI?
A. Yes, I see that.
Q. All right. Does this document suggest to you that McCrone and Associates identified fibers of asbestos in samples of ore from a Vermont mine owned by the Windsor Mineral Company which were used in the production of cosmetic talc, HC?
MR. FROST: Objection.
THE WITNESS: I have no knowledge of the connection between

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these two documents.
For example, after this testing, were these samples actually used? I can't tell.
It says "amphibole." Which amphibole? Is it one of the regulated amphibole minerals?
QUESTIONS BY MR. FINCH:
Q. It says "fibers of asbestos," correct?
A. It does say "fibers of asbestos." I would ask, how are they defining that?
This was 1975, and there's no explicit explanation here, so I would wonder how they defined that.
So there's many murky things about this document that make me feel like it's being taken out of context.
Q. And if you were going to analyze this document as a scientist, isn't it correct that you would want to see the photomicrographs that McCrone and Associates took and their analyses, both chemical analyses and any other analyses, they

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provided on the documents?
MR. CHACHKES: Objection.
THE WITNESS: Well, I would ask why, as a scientist, I would want to analyze something like this. I would much prefer to analyze a formal report.
QUESTIONS BY MR. FINCH:
Q. If there were a formal report that once upon a time went along with this and contained photomicrographs -- you okay, ma'am? -- or count -- or count sheets or diffraction patterns, would that be information that you would want to consider to analyze whether or not this letter report from McCrone is accurate and reliable?
MR. CHACHKES: Objection.
THE WITNESS: I don't know. We're going far outside the scope of my remit here, which is to evaluate methodology. But I would say, again, there's no context here. There's no -- I have no way of knowing whether the samples in this report are ones that were ever even involved in a mine

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or even used in commercial production. There's not enough information here to make a judgment.

And if they weren't used, then there wouldn't be any -- need to be any more information.

QUESTIONS BY MR. FINCH:

Q. But in order to understand the context, you agree with me that it would be useful to have the backup data that underlies this report?

MR. CHACHKES: Objection.

THE WITNESS: I'm still not understanding why I would want to be examining this report. I'm supposed to be evaluating methodology here, and you're asking me to evaluate a random report with no context about which I know nothing.

There's nothing in here to indicate that the samples they're talking about were ever -- ever even had anything to do with talc that was actually produced from Vermont mines or anywhere else.

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QUESTIONS BY MR. FINCH:

Q. I want you to assume that these documents are contemporaneous reports of McCrone analyses of talc from the very mines that Johnson & Johnson used to source its baby powder in the 1970s, and that in Exhibits 18 and 19 McCrone states that they found fibers of asbestos, in the case of Exhibit 18, and Exhibit 19, confirmed asbestos visual on page 2, in multiple samples of talc ore from the Vermont mines that were used to source cosmetic talcum products.

A. So --

MR. CHACHKES: So -- go ahead.

QUESTIONS BY MR. FINCH:

Q. So based on that set of assumptions, Doctor, do you have any basis to say that this is not evidence that one of the minerals that can potentially be found in talc from Vermont is amphibole asbestos?

MR. CHACHKES: So objection. You don't have to take those assumptions.

You shouldn't be

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misrepresenting the documents.

So with that note...

THE WITNESS: I choose not to answer.

QUESTIONS BY MR. FINCH:

Q. You have not, as part of your work in this case, asked Johnson & Johnson for all of the testing results that have ever been done on either the talc ore or the baby powder product itself, correct?

A. So my role here was to evaluate methodology used by Longo and Rigler. It was not to evaluate testing protocols used by Johnson & Johnson.

I have no opinion of -- no knowledge of those and no opinion on those.

Q. Are you familiar with the testing protocol J41 -- J4-1?

A. I don't believe so.

Q. It's the testing protocol that the talc manufacturers voluntarily put into place in the mid-'70s for the analysis of asbestos in talc.

Are you familiar with that?

MR. LOCKE: Objection.

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MR. CHACHKES: Objection.

THE WITNESS: No.

QUESTIONS BY MR. FINCH:

Q. If I were to tell you that it is a combination of XRD and optical microscopy, is the J4 method, would you agree with me that those two methodologies would not be able to detect asbestos fibers in talc at a concentration below 0.1 percent?

MR. CHACHKES: Objection.

MR. LOCKE: Objection.

THE WITNESS: Oh, I would need a lot more information than your random statement that it meets XRD and optical microscopy. I'd need to examine that document to be able to render an opinion.

QUESTIONS BY MR. FINCH:

Q. You're not -- I think you just said two questions ago you're not giving any opinions that Johnson & Johnson's historical methodologies for testing its talc for the presence of asbestos are accurate or reliable; is that correct?

MR. CHACHKES: Objection.

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THE WITNESS: I'm not giving any opinion, period, on testing procedures from Johnson & Johnson because I have no knowledge of them and, therefore, cannot comment in any way.
QUESTIONS BY MR. FINCH:
Q. All right. On page 33 of your report, you reference a term "unspecified constant."
Do you see that?
A. Yes.
MR. CHACHKES: I'm sorry, on page 33?
MR. FINCH: Page 33 of her report.
THE WITNESS: Yep, it's right here.
MR. CHACHKES: Okay. Thanks.
QUESTIONS BY MR. FINCH:
Q. How do you calculate the camera constant for doing SAED?
A. So the camera constant is calibrated for each individual apparatus using a reference standard, and it allows you

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to relate the spacial distances in an image to actual physical distances. And it varies by instrument, and it is explicitly not provided. Even though the definition of camera constant is given on each page in the diffraction verification document, the actual value for their instrument or instruments is not given.
Q. Could you turn to page 37?
A. (Witness complies.)
Q. What does camera K refer to?
A. I have no idea.
Q. You don't think that refers to camera constant?
A. I was not going to guess.
Q. If that, in fact, does -- are you familiar with the scientific --
A. I am, but in point of fact, it's expressed, you'll notice, in units of pixel per angstrom. And the images in these documents, which are many times scanned, no longer have any pixels.
So even if that is the camera constant, this number is completely useless because there are no pixels in any of these

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images.
Q. Isn't it true --
MR. FINCH: Mark this as the next exhibit. It's Exhibit 21.
(Dyar Exhibit 21 marked for identification.)
QUESTIONS BY MR. FINCH:
Q. In the diffraction verification documents --
A. Uh-huh.
Q. -- in every one there is a field called camera K, camera K, camera K?
A. And in every one it's given in units of pixel per angstrom, which is a useless unit.
So I stand by my statement that the constant is unspecified in terms that are useful enough to allow someone else to interpret the images, which was the point of my statement there.
Q. Okay. So you're saying that -- did you understand camera K to be a reference to camera constant or not?
A. I did not know. There was not enough information. That is not defined

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anywhere in any of the documents I saw.
And even if it had been, I have no way of using that information because there's no pixels in any of the images.
Q. The pixels in the images are the SAED images that you've shown some examples of, for example, on page 28 of your report; is that right?
A. Certainly.
Q. And your -- my understanding is it's your complaint that because the images are not sufficiently clear, you can't verify the camera constant in the diffraction verification worksheets?
A. Yes. Using something that's expressed in pixels per angstrom implies that in order to use it, you would need to be able to count pixels, and that is impossible in these images.
Q. Was it impossible for the operator at the time he or she was analyzing the particle in realtime using the microscope?
A. Presumably the personnel at the Longo, Rigler company are familiar with the

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camera constants for their apparati, yes.
And in fact, they used said camera constants to determine these values that are at the bottom of each of these pages. But I cannot go backwards.
Q. So you can't reverse-engineer it, in other words, and that's your criticism?
A. Correct. These documents do not provide a camera constant in any useful units, thereby making it impossible to corroborate their measurements.
Q. Okay. But in fact they did have a camera constant. You just -- your criticism is that the pixels are not sufficiently clear for you to recalculate their camera constant for each of the diffraction patterns that they were providing data for; is that correct?
MR. CHACHKES: Objection.
MR. LOCKE: Objection.
THE WITNESS: The point of my statement on page 33 is "lacking knowledge of that constant, D spacings cannot be easily verified for the

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patterns in their reports."
And the most important part of that sentence is that there is not enough information here or in any of these diffraction verification documents for me to confirm the D spacing values that they list.
QUESTIONS BY MR. FINCH:
Q. But you would agree with me that on the face of each of the documents there is a notation that has camera K, which a scientist could conclude or should conclude means camera constant for that particular data set, correct?
MR. LOCKE: Objection.
MR. CHACHKES: Objection.
THE WITNESS: That's completely conjectural. I have no reason to expect that. K is not the first letter of the word "constant."
So lacking any information to tell me that that's what it was, and lacking any way to use that value because of the way it's expressed in units, I feel that Drs. Longo and

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Rigler failed to demonstrate that their D spacings are reproducible or verifiable independently.
QUESTIONS BY MR. FINCH:
Q. Do you agree that the anthophyllite solid solution series includes cummingtonite?
A. So I don't believe that that vocabulary is consistent with the current terminology for amphiboles.
If you look on page 607 of my book, you can see that there are about seven minerals which are in the same subgroup of amphibole minerals. And one could say that there might potentially be solid solution amongst all seven of those primary minerals, each of which has from four to seven related species and many subspecies.
So it's a little restrictive to say that those belong to a single solid solution series. It's not really the appropriate term to use for the variation of chemistry in amphibole minerals.
Q. On page 35 you state, last paragraph, "A more comprehensive analysis

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using the American mineralogists crystal structure database shows that more than 1,000 crystal structures have at least one D spacing in the range above."
How many of those 1,000 crystal structures have been found in the Vermont talc mines or the Italian talc mines used by Johnson & Johnson?
A. I have no idea, because I know nothing about the mineralogy of talc mines in Vermont or anywhere else.
Q. On page 37, section F, you identify indefensible or unfeasible D spacings in the Longo and Rigler diffraction verification documents.
It looks to me like you identify two samples where either the measurement itself is bad or they cannot be anthophyllite or both; is that correct?
A. That's correct.
Q. Out of how many different samples?
A. I'd have to look at the diffraction verification documents. I don't recall exactly how many samples they did. I

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know it was six samples.
Q. But it was how many different particles identified?
A. I honestly don't recall. We can certainly look it up.
Q. Would you agree that it's over 180?
A. I honestly don't recall, but I'd be happy to look it up if you --
Q. Okay. Go ahead and look it up.
A. Well, let's get out those diffraction verification documents.
MR. CHACHKES: I'm not trying --
THE WITNESS: Are they not --
MR. FROST: They're 5,000 pages.
THE WITNESS: No, no, he's just talking about the diffraction verification documents. These are the only places where there are any HKL measurements.
QUESTIONS BY MR. FINCH:
Q. Do you have your materials that you reviewed of Dr. Longo's with you?

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MR. CHACHKES: We may. At some point maybe after the break I could check.
MR. FINCH: All right. We'll check that after the break.
THE WITNESS: There are certainly less than 200.
QUESTIONS BY MR. FINCH:
Q. Okay. But 180, we can -- I mean, it's a number we could look up, but --
A. I know for a fact it's only six different samples. In one case there are four different crystals -- or particles, and I don't recall for the other five samples how many particles they looked at.
In some senses it doesn't matter how many particles they looked at, because there is in -- no evidence in any of those diffraction verification documents that they looked at two different zone axes. So my conclusions here about the vast number of samples that they can represent stand.
Q. And your opinion that in order to test a material for asbestos using EPA methodology you have to have a confirmation

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on at least two zone axes is relying on Yamate 3 methodology, correct?
MR. CHACHKES: Objection.
THE WITNESS: It's supported by the Yamate 3 -- or the Yamate recommendation, but it's common sense to anyone who knows anything about crystallography.
And I can explain it as saying that minerals are three-dimensional structures, and so if you only look at it from one angle, you would know nothing about the third dimension and, therefore, your identification is nonunique.
QUESTIONS BY MR. FINCH:
Q. But if the analyst is tilting the goniometer to look at the structure while he's examining it under the electron microscope, isn't it true that he is making a determination in realtime as to whether or not the crystalline structure is or is not consistent with asbestos?
A. According to Dr. Longo's and Rigler's depositions, that's what they're

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doing. They're looking at the screen and making a decision. They're not actually using zone axes. That is what his deposition states.
I give that -- citations to that as footnotes in here, 53, 54 and 55.
Q. Okay. Let's go to page 24 of the report.
A. Uh-huh.
Q. All right. You have on page -- pages 24 through 26 an analysis of the six different analysts in -- working with or for Dr. Longo as to the percentages -- on page 25, the percentages that identify tremolite versus anthophyllite.
On page 26, you've got a graph of mineral species identification from Vermont, and then at the bottom of page 26 you have a time chart that shows tremolite versus anthophyllite over time.
That's Figures 8, 9 and 10 in your report.
A. Yes, and these data were simply taken from the information in Dr. Longo's reports.

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Q. Okay.
A. As seen in the spreadsheets with which we have provided you.
Q. Right, the backup data that you gave us last night.
Let me ask you this --
MR. CHACHKES: Just to be clear, that's Longo's data. You know that, right?
MR. FINCH: I understand that.
MR. CHACHKES: Okay.
MR. FINCH: It's her analysis of Longo's data.
MR. CHACHKES: No, it's Longo's data.
THE WITNESS: Yes. There's no analysis involved here. This is just a graphical representation of the data that are given by Dr. Longo.
MR. FINCH: Okay. All right.
THE WITNESS: That does not involve analysis.
QUESTIONS BY MR. FINCH:
Q. You say that "data in the Longo, Rigler MAS reports indicates that

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samples mined from Vermont appear to have 75 percent anthophyllite and 25 percent tremolite."
What's the basis of that statement?
A. The data that are in the spreadsheet that you were provided with. Calculations are shown there.
Q. In Figure 10, there are reports done in 2017 -- first of all, what are the -- what are the dates on the bottom row of Figure 10?
A. So those are months.
Q. Yes.
A. And they refer to the stated date of analyses that are given on the third page of the TEM reports in all of Dr. Longo's reports.
Q. Would you agree with me that the percentage of tremolite versus the percentage of anthophyllite found in the samples analyzed could depend on the source mine from which it came?
A. Possibly, yes. But in deposition, Dr. Longo stated that all of the

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samples in these reports were assigned at random, and therefore, given his assertion, it seems highly unlikely that this distribution over time would be seen.
Q. Well, if the material that he had to test through the end of 2017 consisted of three bottles of Vermont-sourced talc and the rest from other parts of the world, either Italy or China, and the analysis done in 2018 where the samples -- the majority of which came from Vermont-sourced talc, wouldn't you expect to see -- or isn't it possible you could have a difference in the percentage of tremolite versus the percentage of anthophyllite just based on the source mine from which the material came?
MR. LOCKE: Objection.
MR. CHACHKES: Objection.
THE WITNESS: If, in fact, Dr. Longo had stated something to that effect in his deposition, that might be a possible conclusion.
But the fact is that Dr. Longo says that these samples were assigned at random and, therefore, I have no

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reason to expect or suspect that any particular mine was sourced and provided the analyses at random in this particular time frame.
QUESTIONS BY MR. FINCH:
Q. Isn't it true that in MDL reports he lists out the -- do you know when Dr. Longo received the MDL samples?
A. I'm sure that's buried in the chain of custody documents, but I didn't pay much attention to those because when he received them was not relevant to my mandate of assessing the methodology used.
Q. If five analysts are provided with a total of 32 samples, 29 from an Italian mine, 3 from a Vermont mine, and they're randomly distributed in 2017, isn't it the case that you could have a distribution pattern very similar to Figure 10 if those analysts were provided with many, many more samples from Vermont in 2018, and it was randomly distributed along the five -- the same five people? That is one explanation for this time dichotomy you show in Figure 10, correct?

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MR. FROST: Objection.
THE WITNESS: Boy, that's a lot of hypotheticals there.
I'd have to sit down and look at the math and review my data, which are not -- which were provided to you but not included in this report, that suggests that there's a 75 percent to 25 percent of anthophyllite to tremolite.
So, for example, in your case, you're saying that in 2017 perhaps those samples were all from Vermont. Yet if they were from Vermont, then we should have seen a lot more anthophyllite, 75 percent more to be precise.
So I'm not sure where you're going with that question.
QUESTIONS BY MR. FINCH:
Q. No, you've got it backwards.
If virtually all the samples in 2017 up through March of 2018 came --
A. Are tremolite.
Q. -- from sources other than

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Vermont --
A. Ah.
Q. -- you would expect to see a lot more tremolite than anthophyllite, correct?
MR. LOCKE: Objection.
THE WITNESS: That's not true, because I actually don't know what the percentage of anthophyllite to tremolite is in the other mines. I only have -- happen to know it for Vermont.
QUESTIONS BY MR. FINCH:
Q. If, in fact, it's 100 percent tremolite and zero percent anthophyllite in the other mines, wouldn't the graphic Figure 10 look exactly the same?
You'd see a lot more tremolite in the samples that Dr. Longo was able to test prior to March of 2017 where the mines were predominantly Italy, sources predominantly Italy, versus the MDL samples where the source was predominantly Vermont?
MR. FROST: Objection.
THE WITNESS: It seems to me

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that you're bending your assertions to match the graph. And I'd rather know the facts on what the distributions of species are in these other deposits, which I don't, in order to support or negate your hypothesis.
QUESTIONS BY MR. FINCH:
Q. Okay. Isn't it true that you don't know the distribution of tremolite versus anthophyllite in the samples from outside of Vermont that Dr. Longo's laboratory tested? Correct?
MR. CHACHKES: Objection.
THE WITNESS: That is correct. All I know is that Dr. Longo stated that the selection and assignment of samples in this study was random. And, therefore, I have no reason to believe your conjecture that there was a bias in geographical assignment of these samples over time, because Dr. Longo himself said that there was not. He said that they were assigned at random.

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QUESTIONS BY MR. FINCH:
Q. He said they were assigned at random. He was not asked what percentage of the -- isn't it fair to conclude that it was random for the samples that he had at the time they were being tested, and he didn't go back and randomly assign all the samples to his analysts after he got all the MDL samples?
MR. CHACHKES: Objection.
THE WITNESS: You know, there's not enough information to be able to answer that question.
I did not compile the information on when specific samples were obtained, so I can't either support or negate your assertion without reconsidering the data in the report.
QUESTIONS BY MR. FINCH:
Q. All right. Would you agree with me that Mehrdad Motamedi and Anthony Keaton had very consistent findings of tremolite versus anthophyllite for the 179 particles that Motamedi examined and Keaton's

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289 particles?
A. Actually, no, I would say it's kind of odd that Keaton identified a fair number of ferro-anthophyllites and Motamedi did not.
Q. Do you know the source of the talc for each of the six analysts -- each of the five analysts identified in Figure 8? How many -- how many Vermont-sourced talc did Jayme Callan analyze versus other places; how many Motamedi did; how many Keaton did?
A. Well, that information is in Figure 8.
Q. How is it in Figure 8? It just says what the --
A. It says where it came from, either Vermont or other.
Q. That's in Figure 9.
A. I'm sorry, Figure 9.
Q. What about 8?
A. No, I didn't happen to figure out a way to color code Figure 8 to indicate where the samples came from. I could have done that, I suppose, but it didn't even occur to me to do that.

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I'm looking at methodology and I'm trying to assess whether the analysts who did this work were consistent and, therefore, I made graphical representations of the data in their own reports, but, no, I did not make yet another graphical representation that would have included both the minerals identified and the locations from which they came.
Q. Would you agree with me that the breakdown as between tremolite and anthophyllite could vary among analysts if one of the analysts was reviewing more Italian-sourced talc and the other analyst was reviewing more Vermont-sourced talc?
A. I don't have enough information to know anything about the ratio of those in the other mines. So I can't address that question.
In point of fact, in the information that I have gave you, you will see that I did not know the mine locations for many, many samples, but I did happen to know the mine location for Vermont for several, so that's how I was able to come up

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with that 75/25 value for Vermont.
MR. FINCH: This is probably a good place to take another break.
MR. CHACHKES: Okay.
VIDEOGRAPHER: The time is 3:35 p.m. Off the record.
(Off the record at 3:35 p.m.)
VIDEOGRAPHER: Okay. All right. We are now back on the record. The time is 3:54 p.m.
QUESTIONS BY MR. FINCH:
Q. We're back on the record after a short break.
Ms. Darby Dyar, do you have Exhibit 19 in your pile still?
A. Yes. Somewhere. Yes.
Q. Do you consider yourself to be an expert in using electron microscopy and selected area diffraction to determine the extent of amphiboles or serpentine contamination in samples of talc?
A. So, first of all, no one would use SAED to determine the extent of amphiboles or serpentine contamination because you can only do one at a time. So

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that's sort of a strange question.
Do I consider myself to be an expert in using electron microscopy and SAED to identify minerals? Yes.
Q. Okay. Exhibit 19 is a report from McCrone Associates where they say, "We've examined two groups of samples using electron microscopy and selected area diffraction to determine the extent of amphiboles or serpentine contamination in these two groups of samples."
And then they describe these as talc samples from your orebody, being the Windsor Mineral company's orebody.
"The second grade consisted of seven samples which were sent to us subsequently to be analyzed separately."
And then it has their general conclusions on pages 2, 3, 4 of the report.
Do you see that?
MR. CHACHKES: Objection.
THE WITNESS: It will take me a while to read through these five pages, but I certainly see the pages.

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QUESTIONS BY MR. FINCH:
Q. You were asked by Johnson & Johnson to evaluate the methodology that Dr. Longo and Rigler followed to analyze samples of talc to determine whether there's asbestos in them or not, correct?
That was your charge here?
A. I was asked to evaluate the methodology -- methodology -- methodology of Drs. Longo and Rigler, yes, that is why we're all here.
Q. If you were asked by Johnson & Johnson to analyze both the methodology and the conclusions of Walter McCrone Associates in this July 1975 report, what information or data or materials would you want to see?
MR. CHACHKES: Objection.
THE WITNESS: That's kind of a strange hypothetical. Because that's not enough information in here for me to even evaluate what their methodology was.
QUESTIONS BY MR. FINCH:
Q. Well, they state that they used electron microscopes and selected area

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diffraction to determine the extent of amphiboles or serpentine contamination of two groups of talc samples.
So they describe, at least generally, the tools and methodology they are using in their July 1975 report, correct?
MR. CHACHKES: Objection.
THE WITNESS: I don't know. I would have to look at this more carefully than just this brief inspection, but, for example, if they used SAED, did they do two different zone axes? I don't know. Perhaps if I read -- had the time to sit down and read this, I might find that out.
But all they say is electron microscopy. I don't know what that means. Does that mean SAED using an electron microscope, or does that mean they did something else other than SAED? Unclear.
QUESTIONS BY MR. FINCH:
Q. Okay. What information would you want to see in order to evaluate what they did and whether -- or whether or not you

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agreed with their conclusions?
A. So in my report I referred to in -- particularly the Yamate document which we've already discussed on this day that says two zone axis measurements and an EDS pattern are usually enough to identify an asbestos mineral.
But there's no information in the very brief, out-of-context document about samples that I don't know where they came from or whether these were actually used as ore for anything having to do with talcum powder. I don't know.
Q. All right. Would you -- one of the things, I assume, that you would want to look at would be the EDS, EDXA printouts of their electron microscopes if they used EDS, EDXA to analyze the chemical composition of the structures they were looking at.
Is that one item of data you would want to see to evaluate their methodology in coming to this report for Windsor Mineral?
MR. CHACHKES: Objection.
THE WITNESS: So, again, this

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is kind of an extreme hypothetical. I return to the Yamate paper which says that to identify asbestos you need two SAED patterns and some EDS information.
QUESTIONS BY MR. FINCH:
Q. Okay. So we'd want to see SAED patterns, which are taken at least two different zone axes, correct?
A. Correct.
Q. You'd want to see EDS information, correct?
A. That's what I just said, yes.
Q. Would you want to see photomicrographs of the structures they were examining under the microscope to see what you could learn about their morphology or aspect ratio?
MR. CHACHKES: Objection.
THE WITNESS: All of that depends on what the goal of the testing is.
This testing says they found amphiboles, but it doesn't -- but there's no information here that would

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suggest that they are asbestiform amphiboles.
And in fact, you'd think that if it's such a rare thing that they would actually note if it was asbestiform, and it's not noted as such in here.
QUESTIONS BY MR. FINCH:
Q. Doesn't it say in Table 1 and Table 2 confirmed asbestos visual and then description of sample content of sediment, asbestos?
A. It gives the word "visual," which does not instill in me a lot of confidence that it's actually either. Visual of what? Visual of the SAED pattern? Visual of the image they were looking at down the electron microscope.
There's -- one wonders if there's more to this document and what the context is, and whether these samples were even used in talcum powder. Can't tell any of that from here.
I don't know what the word "low" means, for example.

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Q. Well, would you want to see their count sheets, for example?
MR. CHACHKES: Objection.
QUESTIONS BY MR. FINCH:
Q. To evaluate their methodology and conclusions?
MR. CHACHKES: Objection.
THE WITNESS: I find this question kind of too hypothetical. If they existed, I would want all the information that they had available. But in particular, I would want the SAED zone axis information and the EDS quantitative information to the extent that that was available in 1975.
QUESTIONS BY MR. FINCH:
Q. I want you to assume that you are provided with a hundred samples of talc by Johnson & Johnson and asked to evaluate it for the purpose of determining whether or not it contains asbestiform asbestos fibers.
What methodology would you use, what would you do step by step to analyze each particular talc sample?
MR. FROST: Objection.

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THE WITNESS: I'm not exactly sure how this question is appropriate to my mandate, which was to evaluate the methodology used by someone else.
I have not yet been asked to devise my own methodology, and so it's hard for me to make a definitive statement of that.
In my report I say that Drs. Longo and Rigler should have followed the Yamate recommendation of two zone axes and an EDS pattern, and I also say that the Su method, which uses PLM, is useful in identifying asbestos.
So if I were going to design my own protocol, in vague terms, it would be some combination of those, but that's all I could say without further study.
QUESTIONS BY MR. FINCH:
Q. Am I correct that you have never designed a protocol for testing talc to determine whether or not it has asbestos fibers in it?

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A. I've designed many, many analytical protocols for a wide range of instrumentation, but it is correct to say that I have never devised a protocol for analyzing asbestos in anything.
Q. Okay. And is it correct to say that you have never in your professional work relied on the published protocol that are out there for analyzing the presence of asbestos in anything?
A. In my research, I have consistently relied on these tools for the identification of a wide range of minerals.
What was your question?
But I have never had the need in my professional work to rely on any published protocol for analyzing the presence of asbestos.
Q. Okay. Do you draw a distinction in your mind between the tools that a scientist uses to determine the nature of a mineral and the protocol that a scientist follows to determine the nature of a mineral?
A. Well, the tools are just the

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pencils of a -- of a mineralogist, if you will, and the protocol is that you're trained to use the pencils.

So I don't really understand the question.

Q. Okay. Well, the tools -- would you agree with me that one tool that is useful to determine whether or not there is asbestos in a mineral is a polarized light microscope?

A. Yes.

Q. Would you agree with me that another tool that is useful to determine whether or not there is asbestos in a mineral is a transmission electron microscope?

A. Yes.

Q. Would you agree with me that another tool that is useful to determine whether or not there's asbestos in a mineral is a scanning electron microscope?

A. Yes.

Q. Do you view SAED as a tool or a protocol?

A. I view it as a technique.

Q. Okay. Do you agree that SAED

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is a useful technique for determining the presence of asbestos in a mineral?

A. No, because as with all the previous questions, some of these techniques only tell you which mineral species is present.

So in order to determine whether something is asbestos, of course, part of the answer is understanding the chemistry, part of the answer is understanding the crystal chemistry, and part of the answer is evaluating mineralogy -- sorry, morphology.

So each of these techniques that we've just discussed here treat a different aspect of the definition of asbestos that's given in my report.

Q. Okay. And I didn't ask you whether or not SAED is sufficient by itself -- is technique that's sufficient by itself for determining the presence of asbestos in a mineral.

I'm asking whether using the technique of SAED is a useful technique for determining the presence of asbestos in a

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mineral if it is used in conjunction with other techniques?

A. Asbestos in a mineral? I'm not sure what you mean by that.

Q. Asbestos in talc.

A. No, strictly speaking I'm going to reverse my previous answer.

SAED can't tell you whether asbestos is present because SAED cannot tell you the -- anything about the morphology of the particle. SAED can only tell you what the crystal structure is.

Q. Again, my question is not whether SAED by itself can tell you definitively whether a particle is asbestos or not.

My question is: Is SAED a useful technique that a scientist should follow if they're analyzing a sample of talc and they want to determine whether or not there is asbestos in it or not?

A. SAED is useful for answering that question, yes.

Q. Is EDS, EDXA useful for answering the question and analyzing a sample

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of talc to determine whether or not there's asbestos in it?

A. Again, let's be absolutely clear here. EDS only tells you something about the composition, but knowing something about the composition may, in fact, inform the question of whether or not there is one of the six regulated asbestos mineral species present, yes.

Q. In order for a scientist to conclude that there is asbestos present in talc, is it your view that he or she should test the sample using EDXA with two zone axes -- excuse me, using EDXA, full stop, SAED with two zone axes, PLM and doing a statistical test on the aspect ratios if there's enough fibers to look at to analyze that?

A. If it's -- if it's all done properly, yes.

Q. Okay. So the four techniques to determine whether or not talc contains asbestos are EDXA, SAED, PLM, and some kind of statistical test on the aspect ratios to determine whether it's asbestiform or

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non-asbestiform; is that correct?
A. It doesn't necessarily have to be the aspect ratios, but some kind of statistical test on the measurements of the particle sizes -- size dimensions, yes.
Q. Any other technique that you regard as necessary to determine whether or not talc contains asbestos?
MR. FROST: Objection. Form.
THE WITNESS: I think that combination of techniques, if done properly, which Drs. Longo and Rigler don't seem to know how to do, would be sufficient to identify impurities that occur in talc as being one of the six regulated asbestos mineral species, yes.
But only if they're done properly. And, of course, my report details the many problems with the way they were done by Drs. Longo and Rigler.
QUESTIONS BY MR. FINCH:
Q. Does PLM allow you to positively identify asbestos fibers?

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A. If done correctly, it may.
So here's the problem, polarized light microscopy relies on two different kinds of information: One information is about the dimension of the particle and if the particle is bigger than about 2.5 microns, it can be seen with PLM. So that's one thing.
And then the other thing is PLM relies on refractive index, and generally speaking you look at it in two directions. So assuming that the particle was big enough to see and assuming that the correct series of refractive index measurements were made as represented by Su who says use 10 to 20 different refractive index oils and look at many different grains, if all of that was done properly, then, yes, PLM can potentially be used to identify asbestos minerals.
So, again, it's if done properly. And, of course, as I said, if the dimensions of the grain are such that they can be seen under polarized light -- under PLM.
Q. All right. On page 46 you said

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that there's ten instances where the Longo, Rigler reports identify concentrations of asbestos by the Blount PLM method that are well above the sensitivity limits ISO PLM.
What do you mean by that?
A. So those are given in the table at the top of page 47.
So in other words, there's an inconsistency here because the Blount PLM test, which is supposedly more sensitive than the ISO PLM test, registers no asbestos. So it's quite an inconsistency here that the other technique is finding unusual and unreproducible amounts.
Q. You're talking about the table at the top of 47?
A. Correct.
Where I'm contrasting the Longo, Rigler PLM results with the ones from J3.
Q. Okay. Do you know how much time the analysts at J3 spent to analyze each sample under PLM versus how much time the analysts in Longo's labs spent to analyze the samples using PLM?

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A. I have no information on that. I don't believe that's stated anywhere in the reports.
Q. Do you have an understanding of what is the typical time an analyst would spend to identify by PLM asbestos in an asbestos-containing bulk material where you believe it's likely to be there?
A. So in other words, if you handed me a sample of salt, told me it was salt, and then asked me to identify it under a polarized light microscope, how long would it take me? Not very long.
Q. 10 to 15 minutes?
A. Maybe.
Q. Do you have any understanding as to how much material Dr. Longo's lab analyzed using the Blount PLM method as compared to J3 Resources as reflected in the table at the top of page 47?
A. I don't recall that information. I don't recall if it was in the report. I wasn't paying attention to how much material was there because it's really irrelevant. In PLM you're looking at a very

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small area, and so how much material he had to start out with is completely irrelevant. It's what ended up on the slide and being inspected by PLM that would be relevant.

Q. In your Longo, Rigler, Blount PLM weight percentage, what's the denominator that you're using for that?

Is that the material after it's been spun out using the Blount method or is that before?

A. Those are just the results in the report. I don't recall. Those are your numbers. I just tabulated them and put them in my report. I don't recall.

Q. Do you know what an aberrational corrective lens is for a polarized light microscope?

A. Yes.

Q. Can you explain that?

A. There's different kinds of aberration corrections. It's basically a piece of glass with optical properties that change the appearance of the image that you see under the microscope.

Q. Could the fact that one

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laboratory used an aberrational corrective lens versus a standard lens affect the ability to detect asbestos in a sample of talc?

A. Well, it would depend on what kind of aberrational microscope it was, and it would also depend on how the analysis was done.

So not necessarily, I guess, would be my answer to that.

Q. But it could?

A. It could or it could not, depending on exactly which kind of correction lens you were using.

If you're talking about the lens using {sic} in dispersion staining, that's not necessarily a more accurate method than using a succession of refractive index oils.

Q. Could the amount of time spent looking through the sample to determine whether or not there was any asbestos detected affect the results of one laboratory versus another?

By that mean I mean if one

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laboratory spent 15 minutes looking at each sample by PLM to determine if they found anything that was indicative of an asbestos fiber and the other laboratory spent two hours per sample, could the time spent affect what is found?

A. You know, as a scientist, I don't think in terms of how long a task takes. I think in terms of trying to get the right answer.

So as a scientist, it didn't even occur to me to look at these reports and ask how long something took. I assumed that they took enough time to get the answers that they did.

Q. Would you agree with me just generally, if you're looking for minute amounts of material in a substance, the more time you spend looking for it, if it's there, the higher likelihood that you are to find it than as compared to the less time you spend looking for it?

A. So if you hide a needle in a haystack and you search for ten minutes, you're probably not going to find the needle,

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and if you searched for two days, you might not find the needle. So it kind of depends on the abundance of the impurity that you're looking for.

Q. But do you think --

A. In that case, the difference between two days and ten minutes is not significant.

Q. Have you ever done any analysis to determine whether the difference between two hours of looking at talc with a PLM will make a material difference as compared to looking at it for 15 minutes on a per-sample basis?

A. You know, I teach optical mineralogy, or have taught frequently. Some students can identify a mineral really fast; some students take a long time. Both of them will get to the right answer eventually.

So as I said, as a scientist, I never think in terms of the time it takes. I just think about how good the -- about what is necessary to obtain the result needed. Time is not a thing that's usually relevant to me.

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Q. Am I correct that you did not make any analysis of the time the analysts spent with PLM on the samples in the J3 lab versus the Longo lab?
A. That's correct, and the reason would be that I do not consider time to be relevant to how good their methodology was.
Q. All right. On page 49 you have -- an example of a confusing PLM image is given in Figure 21.
A. Correct.
Q. Am I correct that Figure 21 is a printout of an image that's in the backup materials to Dr. Longo's report?
A. It is one of his dispersion staining images, yes.
Q. Okay. You say, "The view at left is pink because it is a dispersion staining image, which is a special way a plate is inserted in the microscope to make the colors more intense and more diagnostic."
A. In layman's terms, yes, that's what I say.
Q. Why do you conclude that it's a dispersion staining image?

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A. Because the background color is pink, and the action of the dispersion lens is usually to increase the colors that are viewed.
Q. Do you know what an elongation image is?
A. Yes.
Q. What is an elongation image?
A. An elongation image is when you use -- you rotate the microscope to get the -- the image to coincide with the maximum extent of reflective index.
Q. And can an elongation image be done without dispersion staining?
A. Yes.
Q. And it typically is done without dispersion staining, correct?
A. Correct.
MR. FINCH: Can I have the next document?
(Dyar Exhibit 22 marked for identification.)
QUESTIONS BY MR. FINCH:
Q. What are we up to? 22.
So this is Figure 21 out of

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your report; is that correct?
A. I'd have to look, but -- well, actually, I don't think this is Figure 12.
Are we looking at the first one?
This is not Image 21.
Q. Page 49 of your report.
Look at page 49 of your report.
A. Oh, yes -- oh, right, but not this. Okay. Yes.
Q. Okay. Page 49 of your report has -- in the bottom it has a sample number?
A. Yep.
Q. Okay. And what is the sample number?
A. Well, it's too small for me to read.
Q. Okay. I can read it. It says, "M69680-015BL-003, anthophyllite elongation at 400 times."
A. Okay. Thank you.
Q. All right. Section 13 is -- let's go through it page by page.
First of all, it lists the project split number M69680-015BL, correct?

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A. Correct.
Q. Analyzed by Paul Hess on 12/11/2018?
A. That information isn't here, but...
Q. This should be -- do you have the first page of the -- keep going backwards.
A. Ah. This, yes. Okay. Got it.
Q. All right. So sample M69680-015BL is the sample -- M69680-015BL, that's the sample -- it's from the same sample that you're looking at in Figure 21 in your expert witness report.
Right, ma'am?
A. If that's what the label says, then, yes.
Q. Okay. So the first page of Exhibit 22 -- is that 22, ma'am?
A. Yes.
Q. It says Section 13.
The second is a page entitled "PLM Analysis" that has the sample listed, correct?
A. Here?

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Q. Yes.
A. Yeah.
Q. What is the third page of Exhibit --
A. It's an image.
Q. It's an image with a dispersion staining, correct?
MR. CHACHKES: Just to make sure we're on the -- literally the same page, are you looking at the red page or the gold, black page?
MR. FINCH: I'm looking at the gold and black page. Yeah, so you're not on the same page.
THE WITNESS: Yep. Yep.
MR. FINCH: I'm looking at the gold and black page. This is --
MR. CHACHKES: Not that page.
MR. FINCH: This page.
MR. CHACHKES: You're counting from different numbers.
THE WITNESS: Oh, got it. Okay.
QUESTIONS BY MR. FINCH:
Q. This is M69680-015BL-001.

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That's dispersion staining, correct?
A. Well, when you put -- you can use different wave plates to change the color. Often dispersion staining images are pink. It's also possible to have that color from a different kind of wave plate. So I'm not -- I don't think that these -- in some cases they were specifically labeled as such. I don't happen to recall what this one was labeled as.
Q. Well, you said in your report that sample M69680-015BL-003 is a dispersion staining image, correct?
You say that at page 49. "The view of the left is pink because it is a dispersion staining image," right?
A. I do see that, but the same thing could be true with the wave plate. So it doesn't really matter whether it's a dispersion staining image or a -- just a normal wave plate image.
Q. This is --
A. You interpret them differently.
Q. This is an elongation image?
A. That's what you're telling me,

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yes.
Q. That's what it says right on the document, right?
MR. CHACHKES: Now what page are we on?
MR. FINCH: I'm on the page that is identical to the page that's Figure 21 in her expert witness report.
THE WITNESS: That's what it says, elongation, yes.
MR. CHACHKES: No, you're looking at your report. I'm saying which -- what page are you looking at in that Section 13?
MR. FINCH: Well, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13.
13th page of Section 13 --
MR. CHACHKES: Okay.
MR. FINCH: -- of Exhibit 22.
THE WITNESS: Ah, this lovely grain, yes.
MR. FINCH: If you look on the Elmo, I've got it.
THE WITNESS: Yeah, that's

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right. I have it in my report. I know what it looks like.
Here, I'll just look at it on Alex.
QUESTIONS BY MR. FINCH:
Q. And so that is an anthophyllite elongation image, correct?
A. There is no way that's what that is.
Q. And there is -- there's no indication that this is an image taken with dispersion staining, correct, on the picture that's large enough to seen?
A. No, so I might have miswritten that it's a dispersion staining image, but that doesn't change the fact that that is not anthophyllite.
Q. So you were incorrect when you said this was a dispersion staining image; is that true?
MR. LOCKE: Objection.
THE WITNESS: I honestly don't recall.
The focus of analyzing this particular image has nothing to do

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with whether it's a dispersion image or not. It has to do with the ridiculousness of there happening to be an amphibole grain that happens to be exactly the same length as a talc particle and happens to line up exactly along the edge of the talc particle. That's the point of including this figure in the document.

So whether or not it's a dispersion staining image is real pretty irrelevant.

QUESTIONS BY MR. FINCH:

Q. Now, isn't it true that in the previous two images they take a look at the same material from two different rotations? One of it --

A. Yes.

Q. And wouldn't it be the case that if it were a talc particle curled up on edge, it would look different in the M69680-015BL-003?

A. Well, these two images were not taken with the same wave plate. Regardless of whether it was dispersion or not, they're

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not taken -- obviously the colors are different, so they weren't taken under the same conditions, so the colors would be different.

Q. What I'm asking you is, if it were in fact talc rolled up as opposed to anthophyllite, wouldn't it be the case it would appear differently between the image I'm showing you on the Elmo now and the rotated image that's one page behind it?

A. Only if the same wave plate was used in both images.

Q. And you don't know whether that's true or not, do you?

A. One of them says "perpendicular dispersion" and the other one says "elongation," and I don't recall from the report specifically which ones of these is which. I mean -- but clearly they're not under the same conditions. Because when you put a wave plate under a microscope, the colors intensify as seen in the pink background, and this image clearly does not have any kind of wave plate.

Q. Which is the "this" you're

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referring to? The page in front of the elongation image? Page 12?

A. Yeah, it says it's a dispersion staining image, so I guess we have to accept that that's what -- that is what they say it is.

But the other one is not -- clearly not the same wave plate, so one would conclude that it was a different accessory.

Q. "The other one." What's the other one you're referring to?

A. The ones with the pink background.

Because accessories are used in polarizing light microscopes to intensify the colors and change them, and so sometimes the background color is diagnostic of the use of a wave plate.

Q. So you're saying it's your opinion that the images on pages 11, 12 -- excuse me, 10, 11, 12 and 13 of Exhibit 22 are different structures?

A. Well, they're obviously different grains.

Well, that's not true. In one

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case it's the same grain rotated in two directions. Let's see, where is that one?

I'm lost in page space. These aren't numbered, so I don't know which ones you're referring to.

Q. Well, let's -- we established that the elongation image is the 13th page of Exhibit 22, right?

A. Okay. This is page 13, yes.

Q. All right. The page before that is the same sample, anthophyllite perpendicular dispersion, correct?

A. Yes.

Q. And then they rotate the sample, and it is the same sample, anthophyllite parallel dispersion?

A. Well, that's the way it's labeled, yes.

Q. So if it were in fact the same sample they've turned two different ways, would you agree with me that that can't be talc rolled up on its side?

A. No.

Q. Why not?

A. Because the optical properties

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of talc, when you look down on the sheets, are different than the optical properties of talc when you look perpendicular to the sheets.

Q. What's a cross-polar?

A. A cross-polar is a piece of glass that is manufactured in such a way that light vibrating in one direction -- only one direction gets -- passes through, like a polarizing pair of sunglasses.

Q. On page 48 and 49 of your report, you state that the Su 2003 paper requires looking at 10 to 20 grains?

A. I believe I quote from the Su document in here somewhere, yes.

Q. It says, "After 10 to 20 fibers are examined in this way, 10 to 20 fibers were examined in the extinction position."

What's the difference between the extinction position and the original position?

A. So extinction is when the microscope stage is rotated so the grain becomes dark.

It's on page 47, is where the

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quote is from Su.

Q. Uh-huh.

A. And it says pretty clearly, "After 10 to 20 fibers are examined in this way, the fiber with the longest is" -- the longest must be refractive index -- "is assumed to exhibit the refractive index closest to N alpha."

But again, there's -- I don't recall any information in either of these reports that says that they used -- they examined 10 to 20 fibers.

Q. Are there any PLM analyses that Dr. Longo's lab performed that you would agree do show asbestos fibers?

A. No.

Q. Not a single one?

A. No, because let's recall that polarized light microscopy can tell you something about the composition, if properly done, and something about the morphology. And all of the images that I examined contain what I consider to be cleavage fragments, not fibers.

Q. Okay. How did you make the

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determination that the images that you examined contained cleavage fragments and not fibers?

A. Because in my career I've looked at hundreds of thousands of cleavage fragments of minerals under a microscope, and I know what they look like.

The -- and I can consistently identify a cleavage fragment based on having looked at hundreds of thousands of cleavage fragments in my career.

Q. So your opinion that what Dr. Longo's analysts are calling bundles of asbestos fibers are in fact cleavage fragments is based on your looking at hundreds of thousands of cleavage fragments under a microscope throughout your career.

That's what it's based on, right?

A. That, and the research that I did, some of the images that are included in my report such as -- oh, let's see. They're on the morphology section.

So, for example, the paper by Campbell, et al., 1977, gives examples of

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asbestiform versus non-asbestiform particles.

The paper by Gunther in 2010 gives examples of asbestiform and non-asbestiform particles.

The paper by Harper in 2010 gives examples of what asbestiform and non-asbestiform particles look like.

The paper by Pierce in 2017 gives examples of what cleavage fragments look like.

So I would say that I rely on my background of identifying cleavage fragments, along with careful review of the peer-reviewed literature for what constitutes a cleavage fragment, to make my judgment about what is in these samples.

MR. FINCH: Lizzy, can I have the pictures? You know, the redacted pictures?

QUESTIONS BY MR. FINCH:

Q. So am I correct that you can tell by looking at a photomicrograph whether something is a bundle or a cleavage fragment --

MR. CHACHKES: Objection.

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QUESTIONS BY MR. FINCH:
Q. -- based on your expertise and your judgment?
A. That's not what I said.
I said I have identified hundreds of thousands of cleavage fragments in my career. I have very little experience looking at amphibole bundles in thin section, which is why I referred to the literature to find what those images look like.
Q. So you have very little experience of identifying amphibole bundles, correct?
MR. LOCKE: Objection.
MR. CHACHKES: Objection.
THE WITNESS: That's what I said.
QUESTIONS BY MR. FINCH:
Q. You have very little experience in looking for asbestos fibers under a polarized light microscope, correct?
A. I have looked at asbestos fibers under a polarized light microscope in the course of teaching for many years.
Q. How many times?

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A. Oh, we covered the amphibole minerals in mineralogy as a routine thing. I think I've taught mineralogy 20 times, so that would be 20 weeks of my life spent teaching what kind of -- what amphiboles look like.
Q. How about time spent analyzing structures to determine whether or not they are asbestiform asbestos bundles versus something else?
How much time have you spent on a regular basis as part of your academic career doing that?
A. Well, let's go back to my report for a minute and remember that the key methodology for distinguishing between asbestiform and non-asbestiform minerals is by careful analysis of the populations based on the dimensions of the particles.
So that is -- that identification is not something that we would do in mineralogy.
Q. You're talking about the statistical analysis --
A. Correct.

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Q. -- of the particles?
Okay. But you just told me that you had very little experience in reviewing images of asbestiform asbestos bundles under a polarized light microscope or any other kind of light -- any other kind of microscope; is that correct?
MR. CHACHKES: Objection.
THE WITNESS: Boy, I don't think of it as reviewing images. I've looked down a microscope plenty of times at asbestos.
In my experience, most of the asbestos I've looked at has not been bundles.
QUESTIONS BY MR. FINCH:
Q. And my question is: How many times have you looked down a microscope at asbestos fibers?
Is it more than a hundred?
A. Well, now you're changing the question. Before it was about bundles, and now it's about fibers.
How many times have I looked at asbestos under a microscope --

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Q. Yes.
A. -- when I knew it was asbestos from independent means, and I had a macroscopic hand sample, and I myself had prepared the thin section for my class? Literally hundreds.
Q. How about when you're attempting to determine what it is, whether it's asbestos or not?
A. I think we've already established that I was not asked to do testing in this case, and so I have not looked at any -- any of the talc samples, period.
Q. No, my question is: Ever in your career, have you attempted to identify asbestos fibers in a substance where you didn't know what it was?
A. No.
But that's pretty similar to the way Drs. Longo and Rigler treat their analyses as well, because they presume that everything they look at that's a particle is either a bundle or a frag -- sorry, a bundle or a fiber. There's no case in their notes

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where they -- well, it might be a few, where they say something is a cleavage fragment. But they seem to only identify things as one or the other.

MR. FINCH: I'll object and move to strike everything after the word "no."

QUESTIONS BY MR. FINCH:

Q. All right. Let's -- well, actually, there's a few more technical things before we get to this, so...

On page 50 and 51 of your report, you fault Dr. Rigler and Longo for not using point counting to estimate the concentration of asbestos by PLM, correct?

A. Correct. I found no information in their report to indicate they use point counting.

Q. Okay. And you're relying on ISO 22262-1 for your conclusion that point counting is a methodology they should have followed to estimate asbestos by weight?

A. No, I'm relying on the quote from ISO 2262 {sic} to say that the accuracy of a point count is dependent on the number

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of grains counted. That is the context in which that statement is made.

Q. Okay. You're referring to -- your citation is to ISO 22262-1, page 29, right?

A. No, page 50 to 51 where I say, "It is well-recognized that the accuracy of a point count depends on the number of grains counted. This is acknowledged in ISO 22262-2, which says," et cetera, et cetera.

Q. All right. Let's get ISO 22262-1.

A. So that should be on page 29, that quote.

Q. We're on page 29 of ISO 22262-1, is that quote.

A. That's what it says. It looks like there might be an error in that.

Q. Isn't the quote that you're talking about found on page 23?

A. Yeah, that might have been a typo. Although I don't see it on page 23.

Q. Let's see.

A. Let's see if we can find it here. Point counting.

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It's possible that that quote comes from a different ISO document. I'd want to look that up.

Q. Is it possible that it comes from ISO 22262-2?

A. Yeah, let's take a look.

Q. ISO 22262-2, page 23.

A. Interestingly, there are no page numbers in this document.

Q. You have Dyar 5?

A. Yeah.

MR. CHACHKES: I think the page numbers were cut off on our copies.

MR. FINCH: Oh.

QUESTIONS BY MR. FINCH:

Q. It's Section 14.2.3.4.

A. Got it. Ah, yes, this is where the point counting is.

Okay. Now we are all literally on the same page.

Q. Okay. Now, the reference that you have in your report on page 50 and 51 is incorrect, and it should be to ISO 22262-2?

A. Right. So the 1 should be a 2.

Q. At page 23?

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A. In the footnote, yes.

Q. Right. Okay.

Do you agree with me that talc particles and any accessory minerals found in talc can have different sizes?

A. Certainly.

Q. Can they have different thicknesses?

A. Certainly.

Q. Can they have different densities?

A. What do you mean, "can they have different densities?"

Q. Can the talc particles and the accessory minerals have different densities?

A. Certainly.

Q. Can different accessory minerals have different densities?

A. They may.

Q. Can talc particles have different thicknesses from other talc particles?

A. Yes. Or they could be the same.

When you make a grain mount,

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you have no guarantees of what thicknesses of anything are.
Q. And would you agree that the point counting methodology that ISO 22262 refers to -- refers you back to ISO 22262-1 to describe how to do point counting?
A. I don't see that right here. You want to tell me where it says that?
Q. I misspoke. I'm sorry. Section 14.2-3-4 is where it talks about "the statistical reliability of a point count for determination of asbestos depends on the number of asbestos points, not on the total nonempty points examined." That's the quote you have --
A. That's the quote.
Q. -- in your report?
A. Yes.
Q. Okay. And the determination of amphibole in talc is found on page 29 of ISO 22262-2, correct?
MR. CHACHKES: So we don't have page numbers.
MR. FINCH: Page -- it's 16.3.

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16.3.
THE WITNESS: Yep.
QUESTIONS BY MR. FINCH:
Q. Okay. This talks --
A. That describes a centrifuge procedure, yes.
Q. And then it refers you back. It says, "Quantify any asbestiform amphibole in the centrifugate by the point counting procedure specified in 14.2.3," right?
A. Of this document, yes.
Q. Yes. Of ISO 22262-2.
A. Which is the minimum of 20 asbestos points or the equivalent of 13,000 nonempty points. That's what it's referring to, yes.
Q. Right. But if you go to the beginning of Section 14.2.3, that's the section that refers you back to point counting by PLM or SEM that's found on page 20 of the exhibit. It's the beginning of 14.2.3.
A. Yes.
Q. All right. What it states is, "Conventional point counting determines the

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relative projected areas occupied by different particle species on a microscope slide. The integrated relative volumes of different particle species can be calculated from a conventional point count, but only if the particles are all of the same thickness. If the densities of the various particle species are known, the relative weights of the different particle species can be calculated. However, conventional point counting does not produce correct results when applied to the determination of the proportion of asbestos in a mixture of particles with a wide range of different thicknesses and different densities." Did I read that correctly?
A. You did. So I think the point here is twofold. There's not -- there's very little information in the Longo and Rigler reports about the PLM procedures used. And in fact, in most cases when we do this in the laboratory, we sieve the samples so the particles are all the same size. So one normal, logical

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assumption would be that they sieve their particles before they did the PLM analysis. It doesn't say that they did not; it doesn't say that they did. There's not just enough information to know if that's what they did.
Q. Isn't it true that Section 14.2.3 that I just read you said that point counting is not accurate if the -- to determine the proportion of asbestos in a mixture of particles with a wide range of different thicknesses and different densities?
A. That is indeed what the document says. And what I'm telling you is that it's also possible that the data in the Longo, Rigler reports were all from a sieved sample which were, in fact, the same grain size, in which case you would be able to extract useful information out of it. But the germane point here is what's in my report, and that is that the Longo and Rigler analysts didn't do any of this. They just used visual estimates rather than point counting. And they say in their deposition that they used -- compare visual

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comparisons against unspecified and unregulated weight percent standards.
But the results of those are really un -- different from the ones from TEM and, therefore, I consider them to be unreliable.
MR. CHACHKES: Incidentally, we've been going over a little over an hour, if you reach a wrapping-up point.
MR. FINCH: Two more questions, and then we'll stop for a break.
MR. CHACHKES: Always two.
QUESTIONS BY MR. FINCH:
Q. But you have no information about whether or not they had sieved the samples so that all the particles were of the same thickness and the same density before analyzing them, correct?
A. Correct.
Q. And ISO 22262-2, Section 14.2.3, says that point counting does not produce correct results when the asbestos is in a mixture of particles with a wide range of different thicknesses and different densities, correct?
A. But, sir, your point is moot because the point I make in my report is that they didn't even use point counting. So regardless of whether they sieved the samples or not, they didn't do point counting, so it's unclear to me why this is even relevant.
Q. Isn't one reasonable interpretation of ISO 22262-2 is that you're not supposed to do point counting if you're analyzing asbestos found in a material with a wide range of different thicknesses and different densities?
A. No, because it would be entirely possible to sieve the samples to make sure they were all the same grain size.
Q. Does it say anywhere in ISO 22262-2 to sieve all the samples so that they're the same particle and grain size?
A. It doesn't need to say that. It says that if they are a different grain size, you won't get good results. So that implies that if you wanted to get good results, you would sieve the samples, which is the standard protocol.

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Point counting is not just used in the asbestos industry. Point counting is a time-honored geologic technique that's been used for probably a hundred years.
MR. FINCH: Let's take a break.
VIDEOGRAPHER: All right. The time is 4:58 p.m. Off the record.
(Off the record at 4:58 p.m.)
VIDEOGRAPHER: Okay. We are back on the record. The time is 5:32 p.m.
QUESTIONS BY MR. FINCH:
Q. Good afternoon, Professor Darby Dyar.
At page 53 of your report -- this is Exhibit 2 to your deposition, your expert witness report.
A. Sorry, what page is that again?
Q. 53.
A. I'm there.
Q. All right. On page -- at Figure 23 A, images of non-asbestiform particles from Gunther 2010.
Do you see that?
A. Yes.

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Q. Those are images taken from the paper that you and I looked at earlier today, Mickey Gunther's 2010 paper entitled "Defining Asbestos Differences Between the Built and Natural Environments"?
A. Mickey's written a lot of papers, but if that's what I say, then that's the one I reference, yes.
Q. Well, you referred to Gunther 2010. I'm just --
A. Well, hang on. Let's take a look here.
Yes. So between -- yep, that's it. Yep.
Q. Okay.
A. Do you want me to pull that out?
Q. No. No. No.
A. That is indeed where those images came from.
Q. Those images came from what we have marked to our deposition as exhibit -- your Deposition Exhibit 11, correct?
A. Yeah. Might turn the page, I'm sure. Yeah, they're in there.

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Q. Okay. Were you aware at the time that Mr. Gunther wrote this paper that he was serving as an expert witness for the RT Vanderbilt talc company and issuing expert reports that called the materials that were found in Gouverneur talc, Gouverneur, New York, talc, non-asbestiform cleavage fragments as opposed to asbestos -- asbestiform fibers?

MR. CHACHKES: Objection.

THE WITNESS: No, I was not aware of any of that.

QUESTIONS BY MR. FINCH:

Q. Are you aware that there has been an epidemic of mesothelioma from employees of the Gouverneur talc mine in and around the -- who were employed by the Gouverneur talc mine by RT Vanderbilt?

MR. LOCKE: Objection.

THE WITNESS: No, I'm not aware of that.

MR. FROST: Objection.

QUESTIONS BY MR. FINCH:

Q. Are you aware that the EPA Region 9 has criticized Dr. Gunther and

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Mr. Lee's analysis of the distinction between asbestiform and non-asbestiform?

MR. FROST: Objection.

MR. CHACHKES: Objection.

THE WITNESS: No, I'm not aware of that.

And I will also point out that in my report I give examples of non-asbestiform particles from other sources such as Campbell 1977 and -- and Pierce 2017.

QUESTIONS BY MR. FINCH:

Q. All right. Were you aware that Pierce's paper was -- are you aware that Ms. Pierce is an employee --

MR. FINCH: Is it Exponent or ChemRisk?

MR. CHACHKES: Are you aware?

MR. FINCH: I am, but I'm 50-some years old, and remembering everything off the top of my head isn't as easy as it used to be.

QUESTIONS BY MR. FINCH:

Q. Are you aware of the nature of the entity that employs Ms. Pierce and what

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its mission statement is?

MR. CHACHKES: Objection. Form.

THE WITNESS: No, I have no knowledge of that.

QUESTIONS BY MR. FINCH:

Q. You've never heard of Exponent or ChemRisk before?

A. No.

Q. Are you familiar with the terminology "doubt science" or "distraction science"?

MR. CHACHKES: Objection.

THE WITNESS: Never heard that term.

QUESTIONS BY MR. FINCH:

Q. On page 53 of your report you say, "Bundles occur as separable groups of parallel fibers with splayed ends and matted masses as seen in Figure 23 B," as in basketball, right?

A. Yes.

Q. Do you agree with me that bundles do not have to have splayed ends?

A. All I know is that in ISO

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22262-1, bundles are described as structures composed of parallel, smaller diameter fibers attached along these -- along their lengths.

I think the point is that Drs. Longo and Rigler don't define what a bundle is either, so it's unclear what they -- what they mean when they make those assignments.

Q. All right. In page 5 of ISO 22262-1, Section 2.29?

A. Yeah, I think I stole one of yours.

Section 2 point what?

Q. 29, 2.29 in the definitions.

A. Uh-huh.

Q. It says -- it has a definition of fiber bundle, correct?

A. Which is exactly the definition I gave, I believe, yes.

Q. Well, in your report you say "bundles occur as separable groups of parallel fibers with splayed ends and matted masses."

And my question to you was: Do you agree that fiber bundles do not always

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exhibit splayed ends?
A. You know, I've not been called upon to make that judgment call, so I can't say.
Q. Will you agree with me that in the definition of fiber bundle on page 5, Section 2.29 of ISO 22262-1, it states, "A fiber bundle may exhibit diverging fibers at one or both ends"?
A. Yes, it does say -- it does say that, yes.
Q. Okay. And you would agree with me that "may" does not mean "always"?
A. Correct.
But I did not say that bundles are defined as. I just said that's how they occur. Very important distinction.
Q. And you would agree with me -- would you agree with me that you can have a bundle of asbestos fibers without splayed ends at either end of the bundle?
MR. LOCKE: Objection. Asked and answered.
THE WITNESS: The definition in ISO 22262 makes a note that says that.

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QUESTIONS BY MR. FINCH:
Q. It makes a note that it may have splayed ends. It also may not have splayed ends, too, correct?
A. That's correct.
Q. All right. And in Section 7.2.3.7.1 of the same document, page 22?
A. 7.2.3 -- yeah, got it.
Q. It has a description of morphology for -- "morphology that is characteristic of asbestos is as follows," and then it has a description of the morphology characteristics in laboratory samples for PLM identification of the fiber type.
Do you see that?
A. I do see that here.
Q. Okay. It says, "A, the presence of fiber aspect ratios in the range of 20 to 1 or higher for fibers longer than 5 microns."
Do you see that?
A. Yes.
Be careful, you're diverting

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from counting criteria into characteristics for fibers and bundles.
Q. The section is entitled "Morphology," correct?
A. Yes.
Q. And it lists A, B and C, correct?
A. Yes, but it says "generally recognized." It doesn't say "always recognized."
Q. And would you agree with me that it doesn't say that all of these characteristics have to be present in order for it to be morphology consistent with asbestos?
A. It doesn't say that -- it's not clear. The document itself is not clear.
Q. Are you aware of any -- other than the statistical testing using the aspect ratio we'll get to it in a minute, are you aware of any objective way to determine whether or not a structure you're looking at is a bundle or a cleavage fragment in terms of something you can measure using a tool or a technique of --

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A. So before I answer that question, I'd like to back up to your last question and point out that there's a note at the end of this section which says, "This is intended as guidance for analysts, and it is not intended to override the definition of asbestos as presented in 2.9."
So let's make sure we make a note of the fact that these morphology comments here are intended as guidance and not as overriding other considerations elsewhere in the document.
All right. Now --
Q. And it also refers to national regulation. It's not intended to override any national regulation, correct?
A. That's what it says.
Now, if we can go back to your question.
Q. So my question is: Other than the statistical test of aspect ratios on a population basis, is there any quantitative, objective way that you know of to identify the morphology of a bundle as being a bundle of asbestos fibers versus a cleavage

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fragment?
MR. FROST: Objection to form.
THE WITNESS: Let's see.
"Other than."
So we've established that statistical tests of particle dimensions on populations are the best and only way to determine whether something is asbestiform and non-asbestiform.
From an individual particle and a two-dimensional image, it is impossible to make those kinds of judgments.
QUESTIONS BY MR. FINCH:
Q. Would you agree with me that Section 7.2.3.7.1 says, "In light microscope, the asbestiform habit is generally recognized by the following characteristics," and it lists characteristics that do not discuss the statistical testing of a population of -- on an aspect ratio basis?
A. My interpretation of this document is verbatim what it says, which is this is intended for guidance. It's not

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intended to be, as it says, a way to discriminate between non-asbestiform and asbestiform amphibole populations in a rigorous way.
Q. Okay. On page 23, in the same section, in the text below number 5 --
A. Uh-huh.
Q. -- it has a discussion in the second paragraph that begins "In general."
Do you see that?
A. Yes.
Q. Okay. ISO 22262-1 states, "In general, for this part of ISO 22262, the presence of either the asbestiform or the non-asbestiform analogs of tremolite and actinolite, anthophyllite or richterite, winchite, can usually be specified. If the majority of the amphibole fibers longer than 5 microns have aspect ratios equal to or lower than 5 to 1, and if the fibers do not exhibit any of the characteristics in C" --
Which is referring back to page 22, correct?
A. Yes.
Q. -- "it can be concluded that

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the amphibole is probably non-asbestiform, with a degree of certainty increasing with decreasing maximum aspect ratio. If any amphibole fibers longer than 5 microns with aspect ratios in the range of 20 to 1 or higher are observed, then it can be concluded that amphibole asbestos is probably present, with a degree of certainty increasing with increasing aspect ratio."
Did I read that correctly?
A. You read it correctly.
Q. And it says, if any amphibole fibers longer than 5 microns with an aspect ratio in the range of 20 or {sic} 1 or higher are observed, then it can be concluded that amphibole asbestos is probably present. Right?
A. That's what it says.
Q. So that means -- "any" means more than 1, correct?
If you've got any amphibole fibers longer than 5 microns with an aspect ratio in the range of 20 or 1 to higher, ISO 22262-1, Section 7.2.3.7.1, says that it can be concluded that amphibole asbestos is

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probably present, with a degree of certainty increasing with increasing aspect ratio?
A. Let us, again, point out that immediately following the paragraph you wrote {sic} it says, "This is intended for guidance for an analyst," first of all.
And second of all, let's go back and look at the populations in this particular situation. And in fact, it says that the average aspect ratio of all particles looked at by Longo and Rigler is 13.34.
So under their own definition -- or under the definition in this document, none of the particles identified by Drs. Longo and Rigler would be considered to be asbestiform. So you're arguing my own point.
Q. Average doesn't mean -- the average -- you said Longo and Rigler found that the average aspect ratio was 13 point something, correct?
A. Correct.
Q. Average is not the same as the longest, correct?

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A. That's correct. But it is also the case that population distribution of non-asbestiform and asbestiform amphiboles would all have some samples since it's an asymptotic distribution potentially in the 20 to 1 range.
Q. Does -- isn't it true that Dr. Longo and Dr. Rigler did find amphibole fibers that were longer than 5 microns which had an aspect ratio of 20 to 1 or higher?
A. I don't know. Very few of them, based on the information in the plot and figure of 28 C, a very, very small percentage of the Longo and Rigler samples have aspect ratios that are greater than 20 to 1.
Q. Okay. And doesn't it say if any amphibole fibers longer -- any meaning any, not average -- any amphibole fibers longer than 5 microns with aspect ratios in the range of 20 to 1 or higher are observed, then it can be concluded that amphibole asbestos is probably present?
That's what ISO 22262-1 says, does it not?

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A. That is what it says, but below that it also says "this is intended only as guidance."
And then it mentions populations, which is, of course, the more appropriate analysis, which is what I've done in the report.
Q. Okay. And in your report when you're analyzing the populations, am I correct that you say that -- you fault Dr. Longo and Rigler for only analyzing the average aspect ratio for particles longer than 5 microns, correct?
MR. CHACHKES: Objection.
THE WITNESS: Yes, that's what I say.
QUESTIONS BY MR. FINCH:
Q. All right. And --
A. Well, in point of fact what I say is that they only counted particles with aspect ratios greater than 5 to 1, which improperly biases their results toward finding an asbestiform particle population, although it was unsuccessful. Because even with that limitation, their mean aspect ratio

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of particles was still 13, which is well below 20 to 1.
Q. Where does it say that the average aspect -- in ISO 22262-1 does it say in Section C, Section 72371, that the average aspect ratio has to be in the range of 20 to 1 or higher?
A. It says, "This is intended as guidance for the analyst to discriminate between non-asbestiform and asbestiform amphibole populations."
So to me it is implied that these measurements would be made on multiple samples in order to accumulate enough data to understand the population represented.
Q. And in analyzing the aspect ratios, am I not correct that in Section 7.2.3.7.1 of ISO 22262-1 they are talking about the aspect ratios for fibers longer than 5 microns? Correct?
A. It just gives a guidance that, yes, if any amphibole fibers longer than 5 microns -- that's what it says there.
Q. And if any amphibole fiber with longer than 5 microns has an aspect ratio of

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20 to 1 or higher, then it could be concluded that amphibole asbestos is probably present.
And this is in a guidance document for analysts to discriminate between non-asbestiform and asbestiform amphibole populations?
A. I think we can agree to disagree here. The term "probably" is used in this sentence, and then it's followed by a note that says that this is intended as guidance to discriminate between populations.
So I believe that the pop -- the use of populations is the absolute paramount, most useful method for discriminating morphologies.
And let's bring it back to the Longo and Rigler report, too. So in the Longo and Rigler report they use TEM to visually distinguish these things, so they are -- their conclusions are not using aspect ratios in any way.
Q. Doesn't Dr. Longo have analysis of aspect ratio of the structures he analyzes that you recreate at --
A. He presents that information in

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his tables, but I believe that in his deposition he indicated that the terminology that's associated with the images is made at the time of acquisition, before there's any analysis -- before any analysis has been undertaken.

Q. Isn't it true -- you say in footnote 94, "Although the longer Rigler MDL reports utilize PLM for evaluating optical properties, the reports do not give aspect ratios for studied particles either in the photomicrographs themselves or in any of the tables."

A. For the PLM data, I believe that is correct.

Q. All right. We just looked at exhibit -- I think it's Exhibit 22, which was Section 13.

A. It's in here somewhere. Here we go.

Q. And am I correct that in multiple places in the PLM images in Exhibit 22 there are measurements of the length of the structure in microns, and in the tables there are -- there are -- there is

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data in the count sheets for each structure as to its length and width which would enable you to calculate an aspect ratio?

A. What did I exactly say in my report?

I was looking for tables that counted aspect ratios, and there is no aspect ratio in this particular document.

Q. Right.

But the data from which one could calculate aspect ratios is available in every count sheet, correct?

A. But that's not what I said.

What I said in my report was, the reports do not give aspect ratios for studied particles.

Q. The reports give you all the data you need to calculate the aspect ratios for every single particle studied, correct?

MR. CHACHKES: Objection.

THE WITNESS: I would have to review the data again to make sure that those are all there. I don't recall.

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QUESTIONS BY MR. FINCH:

Q. An aspect ratio is simply dividing the length by the width, right?

A. That's correct.

But I would point out that many of the images like this one do not include measurements.

Q. But the count sheets do that back up the images, correct?

A. When they are provided.

Q. Did --

A. It's unclear to my -- I'd have to go back and look. It's unclear to me whether both -- whether all the PLM measurements, including those done by Lepoy {phonetic} and those done by Longo and Rigler, included such count sheets.

Q. Okay. You say that --

A. But in any case, it's irrelevant because the population mean of all of these particles is not high enough to be consistent with the presence of a population of asbestiform minerals.

Q. All right. The population mean that Drs. Longo and Rigler calculated was an

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aspect ratio of 13.34, right?

A. By my calculations, yes.

Q. And what publication do you rely upon for your conclusion that it is a requirement under the international standards for analyzing asbestos that the aspect -- the average aspect ratio must be higher than 20 to 1?

MR. CHACHKES: Objection.

THE WITNESS: I don't rely for my conclusion on the requirement that the aspect ratio be higher than 20 to 1. I'm just pointing out, apropos of the discussion we just had about ISO 22262-1, that it happens to mention aspect ratios of greater than 20 to 1.

And I'm pointing out that as it happens, the aspect ratio of all the particles' population measured by Longo and Rigler is significantly lower than that. That's all I'm saying.

(Dyar Exhibit 23 marked for identification.)

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QUESTIONS BY MR. FINCH:
Q. All right. Let's mark this as Exhibit 23. This is Exhibit Number 23, I hope.
Have you ever seen this document before?
A. Nope.
Q. Do you recognize Richard Lee as the president of the organization that Matt Sanchez works for?
A. I assume so. I assume that's what RJ Lee stands for.
Q. And Ann Wylie is the scientist we talked about before. You rely on Dr. Wylie's publications in part for your opinions in this case?
A. Certainly I cited some of Ann's publications, yes.
Q. This is a non-peer-reviewed publication that they put together describing what is asbestos.
Do you see that?
A. I can see that it's from a non-peer-reviewed source, yes.
Q. All right. And on pages 6 and

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7 --
Does your copy have pages at the bottom?
A. Yes, it does.
Q. -- they have pictorial images of asbestos, asbestiform and non-asbestiform materials, correct?
A. Yes.
Q. And have you analyzed each of the structures identified by Dr. Longo's analysts and pictographs taken by Dr. Longo's analysts to determine whether or not they look more like the middle box under asbestiform than any of the materials -- any of the pictures of non-asbestiform on page 7?
A. So the point is that it's very difficult to distinguish images on the basis of one TEM image which is only two-dimensional. You really need multiple measurements of the dimensions of a particle, on multiple particles, in order to make an assertive and a definitive decision.
Q. And one way to do that is to analyze the aspect ratio of particles that are 5 microns long or longer to determine

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both the mean aspect ratio and the outlier aspect ratios, correct?
MR. CHACHKES: Objection.
THE WITNESS: As an analyst, once you have the thing in the TEM, you'd like to collect as much data as possible. And, yes, a way as described in my report to determine the population of aspect ratios represented in your sample is to make multiple measurements, yes.
QUESTIONS BY MR. FINCH:
Q. I believe you said that you have met Ann Wylie but you couldn't pick her out of a crowd; is that correct?
A. Correct.
Q. Have you communicated with her in any way about your work in this case?
A. No.
Q. Have you submitted -- well, let me ask you this: Is your expert report in this case, Exhibit 2, been peer-reviewed?
A. No.
Q. Do you intend to submit it to any peer-reviewed journal?

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A. It would not be appropriate.
Q. Why not?
A. Because it's simply an analysis of reports. It's nothing worthy of a peer-review journal. It's not -- it's not appropriate.
Peer-reviewed journals are for fundamental research, which this is merely a report that critiques something else. Just as I would not ever submit my review of a paper as a peer-review article.
MR. FINCH: Can I have the next document?
(Dyar Exhibit 24 marked for identification.)
QUESTIONS BY MR. FINCH:
Q. Let's mark this as 24.
Do you rely on US Geological Survey's Mineral Commodity profiles for anything, any aspect of your work?
A. No.
Q. Do you agree that the US Geological Survey is a reputable source if one is looking to identify what the US Geological Service considers asbestos to be?

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MR. CHACHKES: Objection.
THE WITNESS: I haven't researched that, so I don't actually have a good answer for that.
QUESTIONS BY MR. FINCH:
Q. You cited to a publication by Wylie and Virta in your expert witness report, correct?
A. That's correct.
Q. And were you aware that's the same Virta who wrote the USGS Mineral Commodity profile "Asbestos" in 2005, by Robert L. Virta?
A. Apparently that's the case.
Q. And do you agree with me that the US Geological Survey Mineral Commodity profile for asbestos is the United States government's definition of what constitutes asbestos from the perspective of the geology scientists that work for the USGS?
MR. CHACHKES: Objection.
THE WITNESS: You know, you've just given me a 56-page document, and we have a very short time left. I'd be happy to use it to evaluate this

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document, but I can't answer your question without actually reading this document.
QUESTIONS BY MR. FINCH:
Q. Does tensile strength have anything to do with determining whether what you see under a microscope is a cleavement fragment -- a cleavage fragment or an asbestos bundle?
A. So I believe we established earlier that the definition of a fiber includes the qualifier that it has to be flexible and have high tensile strength, and that's the definition which is ubiquitous across many different sources.
Q. Is there any peer-reviewed publication that you know of that tells you how to measure tensile strength in an asbestos fiber or bundle which is 20 microns long or less?
A. Well, let's recall that my role here is to assess the methodology used by Drs. Longo and Rigler, not the methodology that they didn't use.
So I have no opinion on that

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because I didn't research that particular area.
Q. Would you agree with me that ISO 22262-1, ISO 22262-2 and the Yamate document on which you rely don't have any techniques or methodologies for measuring tensile strength in order to characterize something as asbestos or not?
A. All of those documents define fibers as having high tensile strength, and they give guidelines for different analytical tools that can be used to characterize different characteristics of particles, but they don't give -- they're not intended to be exclusive.
So, no, I'm not aware that those documents include information on how to do that. Perhaps there's an ISO 66, whatever it is, 4, that will pursue that.
Q. Turn to Table 11 of exhibit -- whatever this next one is.
A. In what?
Q. 24, the Virta US Geological Survey.
A. I'm sorry, page what?

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Q. Page 14, Table 11.
A. Uh-huh.
Q. Properties of asbestos fibers. Do you see that?
A. I see.
Q. All right. There is -- it lists essential composition, crystal system. Do you see that?
A. Uh-huh.
Q. Is that a yes?
A. I do see that.
Q. Okay.
A. The list.
Q. And then there's a -- there is a discussion -- there is a description of flexibility at the bottom, right?
A. Yes.
Q. There's also a discussion or description of tensile strength about two-thirds of the way down the chart, right?
A. There are measurements -- or there are numbers reported there, yes.
Q. All right. Would you agree with me that tremolite asbestos is described as having poor flexibility as compared to

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crocidolite, chrysotile or amosite?
A. Let's see here. I have no idea without reading the paper what this means. You're taking this table and asking me to interpret it completely out of context.
Just because something has poor flexibility doesn't mean that it's not flexible, and the definition is that it has to be flexible.
In fact, the numbers indicated here for tensile strength indicate that these things are flexible.
Q. Well, isn't it true that the tensile strength is measured in thousand pascals?
A. It is reported in thousand pascals, according to this chart.
Q. Right.
And, for example, tremolite and anthophyllite -- let's start with anthophyllite. That's 27,000 pascals or less, right?
A. That's what it says here.
Q. And that is -- and then actinolite is 6,000 pascals or less, correct?

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MR. CHACHKES: Objection.
THE WITNESS: That's what it says here.
QUESTIONS BY MR. FINCH:
Q. And tremolite is 6800 to 55,000, correct?
A. That's what it says here.
Q. Would you agree with me that the low range for tensile strength for tremolite asbestos is two orders of magnitude less than the tensile strength for the low end of crocidolite?
A. According to these numbers, yes, but I have -- would have to have more time to review this document to determine where those numbers came from and how reliable they are.
It looks like some of those come from studies that were done in the 1950s, and I would question the reliability of those.
So that would be my response to this.
And I would also go back and say that quantification of tensile strength

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and flexibility was not done by Drs. Longo and Rigler, and this document makes it clear that it is possible.
So another method -- methodological flaw of this Longo and Rigler report, which you've nicely given me the data for, is that in fact it is possible to measure tensile strength for these particles, and Drs. Longo and Rigler did not do so.
Q. Do you know if the tensile strength measured in this document is from microscopic particles or particles that are large enough to see by the naked eye?
A. Again, I've only looked at this document for a total of three minutes. I have not had adequate time to either read what the explanation says or to go back and look at the references to determine the particle sizes, so I can't answer that question.
Q. Can you point to a source that you would consider reliable for what is the minimum threshold for tensile strength to characterize a given structure as asbestos or not?

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A. I believe I've already stated in this deposition that I am not familiar with the analytical techniques used to measure tensile strength or flexibility because I was -- they were not among the methods used by Drs. Longo and Rigler, and my job here was to assess the methodology.
So this whole issue is not relevant to that particular documents -- those particular documents except as to say they didn't measure this. So...
Q. Do you have any understanding one way or another as to whether OSHA, the Occupational Safety and Health Administration, and MSHA, the Mine Safety and Health Administration, regulate fibrous talc as asbestos?
MR. FROST: Objection.
MR. CHACHKES: Objection.
THE WITNESS: I know nothing about that.
QUESTIONS BY MR. FINCH:
Q. Do you know whether or not IARC considers fibrous talc to be an asbestiform mineral?

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MR. FROST: Objection.
MR. CHACHKES: Objection.
THE WITNESS: I don't recall seeing that in the IARC documents I read, but my focus in these documents was to assess methodology. It wasn't -- it wasn't to consider talc itself.
QUESTIONS BY MR. FINCH:
Q. I notice you don't have any criticism of Dr. Longo and Rigler's conclusions of the particles they find that are fibrous talc; is that correct?
A. I didn't consider them. I considered only the question of methodology as it relates to the presence or absence of asbestiform minerals.
Q. So the methodology they followed to determine the presence or absence of fibrous talc was not a subject of your work or analysis in this report in this case, correct?
MR. CHACHKES: Objection.
THE WITNESS: Talc is not a regulated asbestos mineral and,

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therefore, I did not consider the information in the report relating to it.
MR. FINCH: Time. Stop. Off the record.
VIDEOGRAPHER: Off the record?
MR. FINCH: Off the record. I want to go off the record.
VIDEOGRAPHER: The time is 6:13 p.m. Off the record.
(Off the record at 6:14 p.m.)
VIDEOGRAPHER: The time is 6:22 p.m. Back on record.
(Dyar Exhibit 25 marked for identification.)
QUESTIONS BY MR. FINCH:
Q. Good evening, Professor Darby Dyar. We're back on the record after a short break.
I'm going to put what's been marked as Exhibit 25 in front of you.
I believe you agreed with me earlier today that tensile strength can be measured in pounds per square inch?
A. So when we were looking at the

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USGS report, we saw that those were the units that were used, yes.
Q. Well, the units that were used were pascal joules in the USGS report.
What I also ask you: Isn't it true that pounds per square inch can be a measurement of tensile strength if you're stretching a material as opposed to squishing a material?
MR. FROST: Objection.
THE WITNESS: Not as far as I know.
QUESTIONS BY MR. FINCH:
Q. This is the document from a textbook. This is the article by Badollet cited by the Virta article, "Asbestos: A Mineral of Unparalleled Properties," that describes the physical properties of asbestos.
Do you see that?
A. Yes.
Q. And it's got the tensile strength of the various -- of the six different regulated varieties of asbestos measured in pounds per square inch.

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Do you see that on page 237 at the -- at the second --
A. Well, the first thing I see is that this paper was written 67 years ago, which would make me doubt the accuracy of these measurements, with all due respect to this individual.
Q. Would you --
A. But I'll take a look at page 237.
Q. Yeah.
A. That's --
Q. Tensile strength. They have a measurement in pounds per square inch of the tensile strength of chrysotile, amosite, anthophyllite, crocidolite, tremolite and actinolite.
A. That's a very weird measurement, but that's what they give here, yes.
Q. Okay. And then on Table 7 at page 241, am I correct that they compare the tensile strength of various varieties of asbestos to other types of material?
A. You know, this is a pretty long

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document, and I've only had it in my hand for two minutes. If you give me a while, I could read this.

There is a table that says comparison of tensile strengths, but --

Q. Comparison of tensile strengths of various materials. Table 7, type of material for cotton fiber, the tensile strength is 73,000 to 89,000 pounds per square inch.

Do you see that?

A. I see this table, but again, I would doubt these measurements given that they are 67 years old.

Q. Okay. Do you agree with me that tremolite asbestos has a substantially lower tensile strength than wrought iron, ingot iron, carbon steel, piano steel wire, cotton fiber?

A. I agree that that's what this 67-year-old document says, but again, I would question this source and ask for more modern measurements.

Q. Do you have any more modern measurements of the relationship between the

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tensile strength of tremolite asbestos as compared to something like wrought iron?

A. Again, let's return to the point that my goal was to review the methodology in this report. And since Drs. Longo and Rigler did not consider the topic of flexibility or tensile strength in their report, then I've not studied this and, therefore, cannot render an opinion on this.

Q. On page 243, Figure 35, what does that say that is?

A. Electron micrograph, amosite asbestos times 15200.

Q. And can you put this on the videotape? Just --

VIDEOGRAPHER: So if you put it on the Elmo, it's going to record it.

MR. FINCH: Oh, it's getting recorded. Okay. I thought that was the case, but...

QUESTIONS BY MR. FINCH:

Q. So the authors of this are calling this amosite asbestos?

MR. FROST: Objection.

THE WITNESS: That's what the

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label says in the paper, yes, but I -- again, I have called into question a document that's 67 years old. It's probably more. It was probably written 68 years ago.

QUESTIONS BY MR. FINCH:

Q. 67 years ago the United States was able to develop a hydrogen bomb, correct?

MR. FROST: Objection.

THE WITNESS: That's correct.

QUESTIONS BY MR. FINCH:

Q. Just because technology is old doesn't mean it's -- just because science is old doesn't mean it's outmoded, correct?

MR. FROST: Objection.

THE WITNESS: I don't -- I'm not going to render an opinion on that.

QUESTIONS BY MR. FINCH:

Q. Well, you study rocks found on the moon and Mars, right?

A. As part of my research, yes.

Q. When is the last time anybody put a man on the surface of the moon?

A. 50 years ago.

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Q. Over 50 years ago?

A. Uh-huh.

Q. You -- am I correct that your annual salary as a professor is approximately $125,000 a year?

A. Salaries at Mount Holyoke College are not publicly available, so I don't know where you got that information, and I'm not comfortable indicating my salary.

Q. Okay. How does your compensation that you've been paid by Johnson & Johnson for this report compare to your annual salary from your full-time job as a professor?

A. At the present time, it's hard to say. I have not been doing this very long, so it's hard to say.

And I would also note that I am also employed as a senior scientist at the Planetary Science Institute in Tucson, Arizona, and I receive a considerable proportion of my salary from that organization as well.

Q. How does the -- in percentage terms, how does the compensation that you've

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been paid by Johnson & Johnson in the past four months compare to your total compensation from other sources on an annual basis?

MR. CHACHKES: Objection.

THE WITNESS: It's certainly less than my total compensation from other sources.

QUESTIONS BY MR. FINCH:

Q. Is it 50 percent of your total compensation from other sources?

A. I actually don't know.

My income varies with the number of research grants I have and the number of hours I charge to them, and so it's hard to give a precise answer to that question.

Q. Have you ever been given a research grant by the United States government to study whether or not there is asbestos in any material?

A. No. Not that I recall.

(Dyar Exhibit 26 marked for identification.)

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QUESTIONS BY MR. FINCH:

Q. Last exhibit, I believe, Exhibit 26.

Doctor, Professor Darby Dyar, Exhibit 26 is Johnson & Johnson Consumer Companies Worldwide Specification describing the methodology for the analysis of powdered talc for asbestiform minerals by transmission electron microscopy.

Have you ever seen this document before?

A. No, sir.

Q. Under TEM analysis, you agree with me that what they're talking about here is analyzing talc for asbestiform minerals, right, by TEM?

MR. CHACHKES: Objection.

THE WITNESS: In the 30 seconds since I was handed this document, I have hardly had time to even read the title. But the title says, "Analysis of Powdered Talc for Asbestiform Minerals by Transmission Electron Microscopy."

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QUESTIONS BY MR. FINCH:

Q. Under Section 13.0, TEM analysis.

Do you see that?

A. I see that section, yes.

Q. Do you agree with Johnson & Johnson's definition of fiber?

MR. CHACHKES: Objection.

THE WITNESS: I have defined fiber in my report with a very specific definition which has lots of agreement in -- both in my literature and in government documents.

QUESTIONS BY MR. FINCH:

Q. My question was: Do you agree with Johnson & Johnson's definition of asbestos fiber as found in Exhibit Number 27 {sic}?

MR. CHACHKES: Objection.

QUESTIONS BY MR. FINCH:

Q. 26. Or 26, I think.

A. So this is not the same definition that I use, but on the other hand, I have not had time to read this document. I don't know what the context of this document

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is.

I know nothing about this document and would certainly need more time than the remaining ten minutes to render an opinion on this particular document.

Q. Okay. Suffice it to say you have not compared the methodology followed by Drs. Longo and Rigler to determine whether or not there is asbestiform minerals in talc with the procedure set forth in Johnson & Johnson's TEM 7024 standard?

MR. CHACHKES: Objection.

THE WITNESS: I believe that we have established that I have no information and have not reviewed documents relating to anything having to do with Johnson & Johnson testing procedures because that was not my mandate.

My mandate was to evaluate the methodology used by Drs. Longo and Rigler.

QUESTIONS BY MR. FINCH:

Q. Did you bring any books or materials with you today?

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A. Me personally, no.
Q. Did the lawyer for Johnson & Johnson bring books or materials that you have relied upon as part of your work in this case that are -- some of which might be sitting on the floor behind you today?
A. I know that he brought copies of my two books.
Q. Okay. Can we just get the two -- your two books, just so I can see -- have a picture of them on the record?
MR. CHACHKES: Technically they're mine, I purchased them, but I can hand them out. Just a second.
MR. FINCH: It's an interesting copyright law question as to who has the ultimate ownership --
THE WITNESS: Yeah, you can buy your own so I can get the royalties.
MR. CHACHKES: Yeah, this is -- just for the record, this is -- I purchased this off of Amazon used, so it's -- it might be marked. I don't know.

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QUESTIONS BY MR. FINCH:
Q. Okay. Mineralogy and Optical Mineralogy. This is the book that you wrote with Dr. Gunther in 2008 that I showed you an excerpt of.
VIDEOGRAPHER: You want to put it on the Elmo?
MR. FINCH: Sure.
THE WITNESS: Correct. It actually took us a decade to write this book, but it was published in 2008.
QUESTIONS BY MR. FINCH:
Q. Okay. And what's the other book that you're an author of that you brought with you?
MR. CHACHKES: Counsel brought.
THE WITNESS: Geostatistics Explained, which is listed on my CV and referenced in the report.
QUESTIONS BY MR. FINCH:
Q. This is the -- one of the references that you rely upon for your statistical analysis set forth in the discussion of the population, correct?

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A. I don't actually rely on it. I cite it because I happen to be familiar with it. But the statistical tests in the report are commonplace and can be found in any introductory statistics textbook.
Q. Did you bring anything else with you to the deposition today?
A. No.
Q. Anything else related -- I mean, obviously you brought yourself. I assume you brought a cell phone or something.
But did you bring anything that you reviewed or relied upon as part of your work in this case to the deposition today?
A. Other than the documents that I already referred to?
Q. Yes.
A. No.
Q. You're almost done.
The question pending was: Did you bring anything that you reviewed or relied upon as part of your work in this case to the deposition today.
And you asked me, "Other than the documents I already referred to?" and my

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qualification was "yes."
Other than the documents that you've already referred to, did you bring anything else with you today?
A. No.
Q. All right. Are there any materials you rely on that are not either cited in your expert report or included in your reliance list that is attached to the back of your expert witness report?
A. No.
MR. FINCH: All right. That's all the questions I have at this time.
MR. CHACHKES: I have a few questions. We don't have to take a break.
CROSS-EXAMINATION
QUESTIONS BY MR. CHACHKES:
Q. Mr. Finch keeps referring to you as Ms. Darby Dyar.
Do you have a graduate degree?
A. I do. I have a graduate degree from MIT. And my last name is Dyar. Darby is my middle name.
Q. Professor Dyar, why are you

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qualified to critique the Longo and Rigler expert report?
A. So my qualifications for reviewing this report are outlined in this particular -- in my report, but among them I have a Ph.D. from MIT. I spent a year as a post doc at Cal Tech. I have been in academia for nearly 40 years and have taught mineralogy at least 20 times.
I've written more than 250 papers that were published in peer-reviewed scientific literature. I've reviewed hundreds of scientific documents in keeping with the standards of my profession. And I've worked on dozens of papers involving amphibole mineralogy and serpentine mineralogy.
Q. And have you received any awards in the field of geology and mineralogy?
A. I have. I've been honored to become a fellow of the Mineralogical Society of America, the Geochemical Society, and the Geological Society of America.
I have also received national

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and international awards in recognition of my research excellence, including the Shoemaker award from NASA, the Gilbert award from the geological society, the Holly medal from the Mineralogical Society of Canada, and the Helmholtz award from the German space agency, among others.
Q. Can you talk about your experience with analyzing minerals with PLM?
A. So I first started using PLM as an undergraduate in 1978, which is 41 years ago, and I've used PLM every year since then. I've taught courses in the use of a polarizing light microscope.
It's a routine tool used by me whenever I look at a rock for the first time. I drag out the PLM and take a look at the sample.
Q. Can you talk to -- about your experience with analyzing minerals using visual inspection with a TEM?
A. So, much of my research in the past two decades has involved the field of biomineralization, which is the interaction of microbes in minerals. And in that

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research, it is necessary to use a TEM to make visual examination of the interactions between the microbes and the minerals.
So I'm intimately familiar with these analyses myself and have supervised many undergraduate and graduates' theses that use TEM.
Q. And could you talk about your experience with analyzing minerals using SAED?
A. So in most cases when we analyze something, when we take an image of something with a TEM, we almost always do SAED if it's possible to get a good pattern.
And so SAED patterns also figure in my biomineralization research prominently as well as in my teaching. I should say that TEM and X-ray diffraction in various forms are part of a typical topics covered in a mineralogy course, and certainly I would have covered them in my 20 mineralogy courses.
Q. And can you talk about your experience with analyzing minerals using EDS?
A. So EDS is the poor stepsister

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of the more accurate gold standard for mineral analysis, which is electron probe microanalysis. The two techniques use exactly the same fundamental underlying phenomena, they just have different detectors, which is why EDS is not very sensitive. Electron probe microanalysis is extremely sensitive.
So, in fact, when I was a graduate student, I was involved in a lot of analytical technique development for electron-based measurements of chemistry, and these have evolved into these two different tools.
So I was involved not just at the ground floor of these methods, but there are now things that I use routinely in my research, in particular electron probe microanalysis, because it is much more accurate than EDS.
Q. And to what degree do you routinely use these tools and techniques that have been mentioned with reference to your published papers?
A. So I strive to have 100 percent

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of the research I do culminate in the publication of a paper in a peer-reviewed journal. So all of these techniques are used prominently in my 250 and counting scientific, peer-reviewed papers.

Q. Tell us some of the qualifications you have to critique methodologies for detecting asbestos, in particular.

A. So there's nothing special about asbestos. It's a mineral. Amphibole is amphibole, and the distinction between the many different varieties and species in the amphibole group are very minor. So there's nothing particularly special about analyzing these materials. They're just minerals.

Q. Do you have experience analyzing amphiboles?

A. I think I've written at least 20 or 30 papers about amphiboles using many, many different analytical techniques.

Q. What, if anything, is there about asbestiform amphiboles that make them more or less of a challenge in terms of microscopy techniques that we've been talking

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about today?

A. Nothing in particular. The only challenge would be that sometimes the particle sizes are too small to be resolved with a polarizing light microscope, and you might need to use other techniques in those situations.

MR. CHACHKES: No further questions.

REDIRECT EXAMINATION

QUESTIONS BY MR. FINCH:

Q. 251 peer-reviewed papers; is that what you said, Doctor?

A. You know, that number changes almost daily. I don't actually know what it is right now.

Q. All right. Ballpark 300, plus or minus?

A. Oh, it's definitely not 300. I'm not that fast.

Q. Okay. And I apologize for calling you Professor Darby Dyar. I will -- I thought your name was Darby Dyar, so I apologize for that, ma'am.

A. Thank you.

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Q. Professor Dyar, of your 250 -- you would agree with me 250-plus peer-reviewed papers, right?

A. Correct.

Q. Not a one of them are addressed to the subject of how to identify asbestos in talcum powder, correct?

A. Correct.

Q. Not a one of them is on the subject of how to identify asbestos in bulk materials, correct?

A. Literally that is correct, but let's remember that I use the techniques that are used to identify asbestos in talc routinely, and those are figured -- are featured prominently in many of my papers.

Q. You've never published a peer-reviewed paper where the subject of paper is how to identify asbestos in any substance, correct?

A. Correct.

Q. How much time do you spend in a laboratory on an annual basis analyzing materials to determine if they do or do not contain asbestiform asbestos minerals?

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A. Very little, but I probably spend 3,000 hours a year in a laboratory using all of the same techniques that are used to identify asbestos in talc.

Q. Very little. Is that less than ten hours?

A. Probably.

MR. FINCH: No more questions.

MR. CHACHKES: That's it.

VIDEOGRAPHER: Okay. Stand by, please. One second. Remove your microphones.

The time is 6:45 p.m. This completes today's deposition.

Off the record.

(Deposition concluded at 6:45 p.m.)

- - - - - - -

CERTIFICATE

I, CARRIE A. CAMPBELL, Registered Diplomate Reporter, Certified Realtime Reporter and Certified Shorthand Reporter, do hereby certify that prior to the commencement of the examination, M. Darby Dyar, Ph.D. was duly sworn by me to testify to the truth, the whole truth and nothing but the truth.

I DO FURTHER CERTIFY that the foregoing is a verbatim transcript of the testimony as taken stenographically by and before me at the time, place and on the date hereinbefore set forth, to the best of my ability.

I DO FURTHER CERTIFY that I am neither a relative nor employee nor attorney nor counsel of any of the parties to this action, and that I am neither a relative nor employee of such attorney or counsel, and that I am not financially interested in the action.

____
CARRIE A. CAMPBELL,
NCRA Registered Diplomate Reporter
Certified Realtime Reporter
Notary Public
Dated: April 3, 2019

INSTRUCTIONS TO WITNESS

Please read your deposition over carefully and make any necessary corrections. You should state the reason in the appropriate space on the errata sheet for any corrections that are made.

After doing so, please sign the errata sheet and date it. You are signing same subject to the changes you have noted on the errata sheet, which will be attached to your deposition.

It is imperative that you return the original errata sheet to the deposing attorney within thirty (30) days of receipt of the deposition transcript by you. If you fail to do so, the deposition transcript may be deemed to be accurate and may be used in court.

ACKNOWLEDGMENT OF DEPONENT

I,________________________, do hereby certify that I have read the foregoing pages and that the same is a correct transcription of the answers given by me to the questions therein propounded, except for the corrections or changes in form or substance, if any, noted in the attached Errata Sheet.

____
M. Darby Dyar, Ph.D. DATE

Subscribed and sworn to before me this _______ day of _______________, 20 _____.
My commission expires: _______________

Notary Public

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ERRATA
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PAGE LINE CHANGE/REASON

PAGE	LINE	CHANGE/REASON

LAWYER'S NOTES

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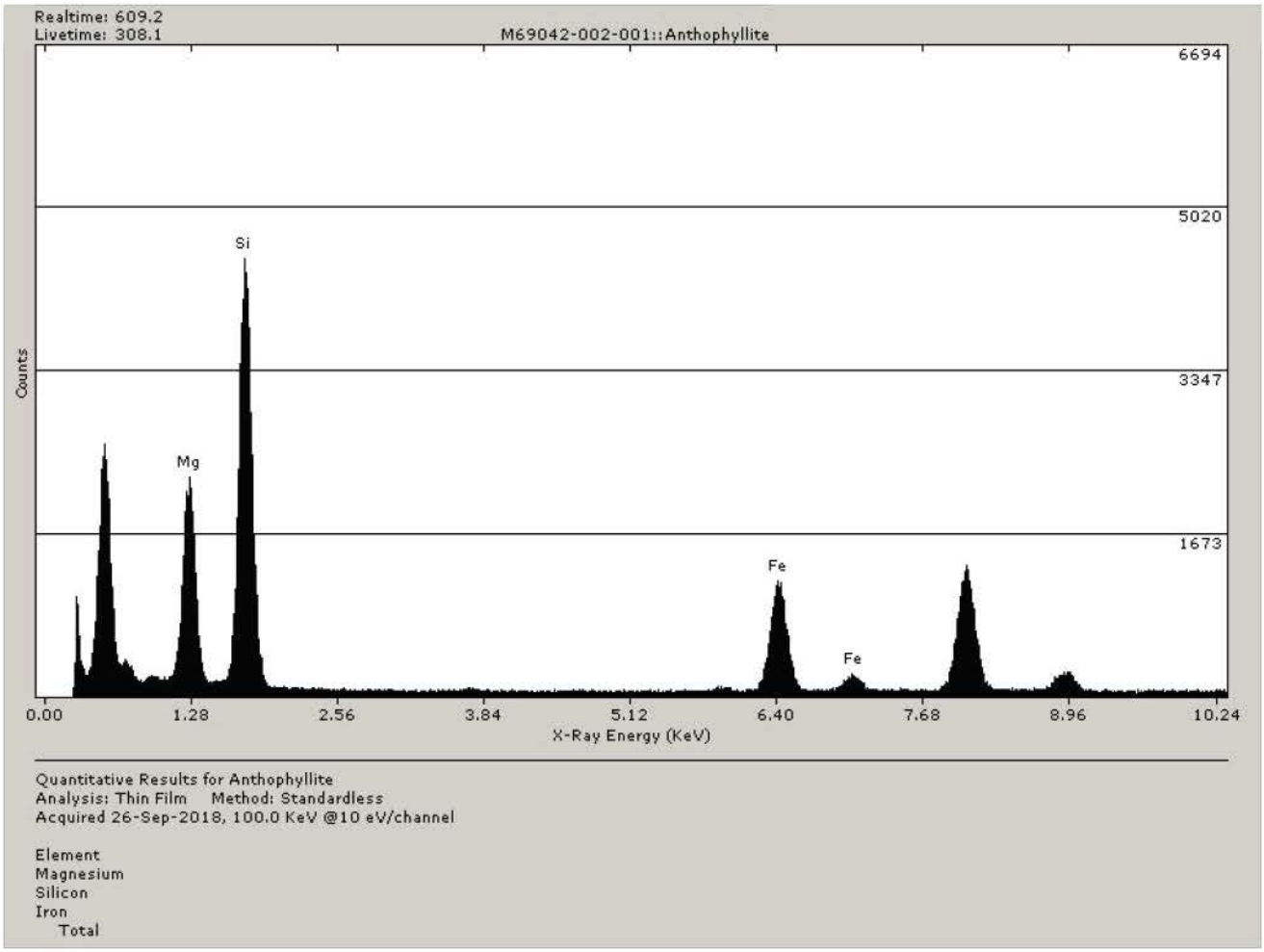
Exhibit 57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Livetime: 308.1
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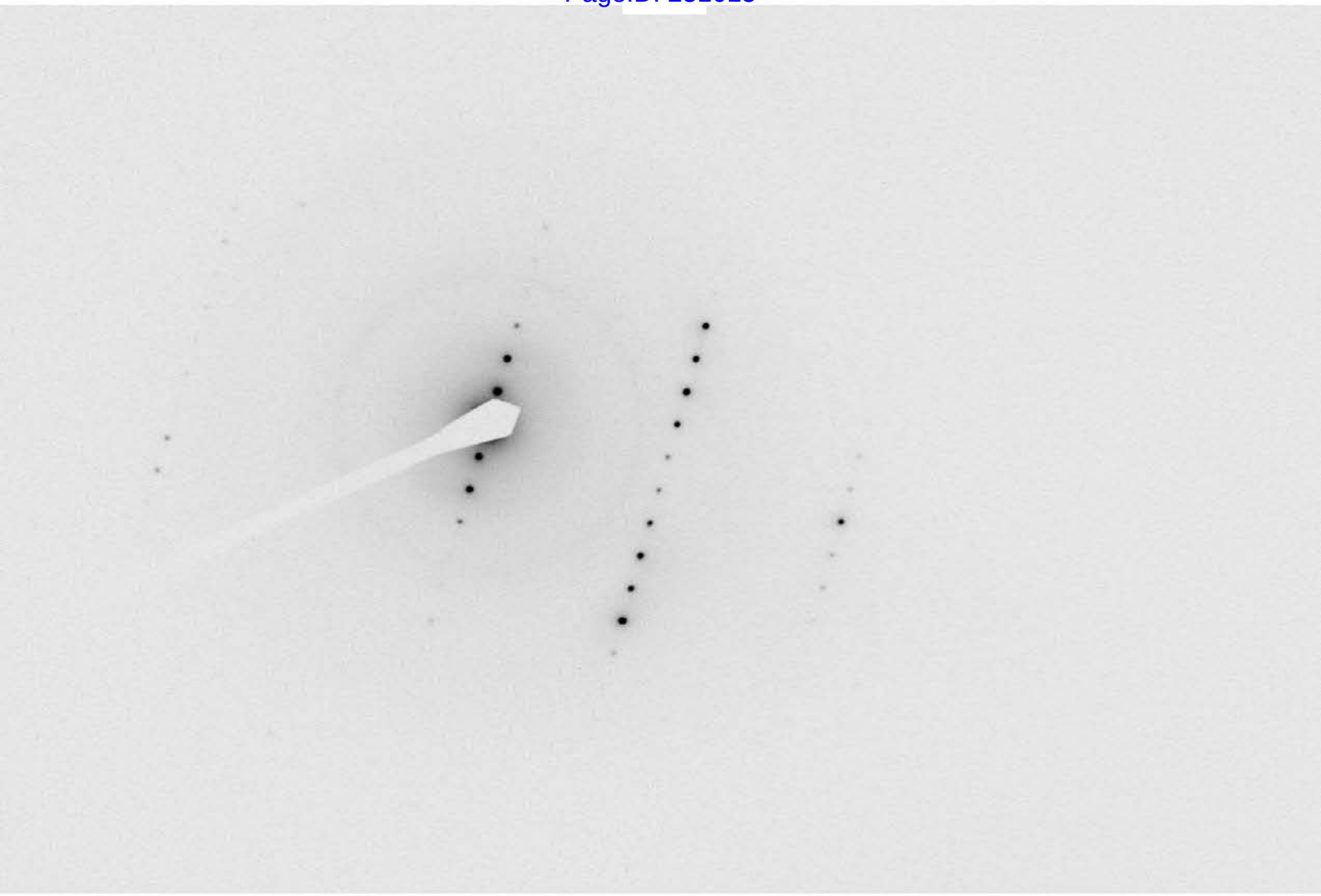
6694
5020
3347
1673
Counts
Si
Mg
Fe
Fe
0.00
1.28
2.56
3.84
5.12
6.40
7.68
8.96
10.24
X-Ray Energy (KeV)
Quantitative Results for Anthophyllite
Analysis: Thin Film Method: Standardless
Acquired 26-Sep-2018, 100.0 KeV @10 eV/channel
Element
Magnesium
Silicon
Iron
Total

Exhibit 58



2 4680 M68503-026-001 Tremolite Diffraction @ 50cm 10/23/2018

Exhibit 59

Johnson & Johnson

J&J Consumer Companies Worldwide Specification

Issued

Strictly Confidential

ANALYSIS OF POWDERED TALC FOR ASBESTIFORM MINERALS BY TRANSMISSION ELECTRON MICROSCOPY

Name	Type
TM7024	Test Method

Revision	1	Owner	Corporate
Issued Date	1995-08-21	Expiration Date	9999-12-31
Geographical Scope	Local	Specification Category	Permanent
Security Classification		Review Interval (Months)	0

Related Information

Template	Test Method Global	SCO	
Co-Owners		Owning Region	North America

Revisions

Name	Rev	State	Description of Change	Reason for Change	Owner	Issued Date	Expiration Date
TM7024	1	Issued			Corporate	1995-08-21	9999-12-31

Approvals

Signer	Role	Organizations	Date/Time
No Objects Found			

Content

Name	Format	File Size
TM7024.doc	generic	35840

Reference Documents

Name	Description

No Objects Found

Related Specifications

Name	Type
No Objects Found	

User Defined Attributes

No Objects Found

Additional Attributes

No Objects Found

Test Method

Company:

- [ ] *Personal Products Worldwide*
- [ ] *Personal Products Company*
- [ ] *Desbiens Products Inc.*
- [ ] *Johnson & Johnson Products Inc.*
- [ ] *Odonto Corporation Ltd.*
- [X] ***Johnson & Johnson Consumer Products Co.***

Document No.: TM7024 **Franchise:** **Location:** ROYSTON, FLUID, KOLMAR

Document Type: Permanent **Expiration Date:** None

Subject: ANALYSIS OF POWDERED TALC FOR ASBESTIFORM MINERALS BY TRANSMISSION ELECTRON MICROSCOPY

REVISION	AUTHORIZATION	DESCRIPTION OF CHANGE
03/08/89	BCR011362	New Test method.
03/21/95	CR020127	Location revised. (Spec. Dept.)
08/21/95	CR020688	Location revised. (Spec. Dept.)

Test Method

Company:

- [ ] *Personal Products Worldwide*
- [ ] *Personal Products Company*
- [ ] *Desbiens Products Inc.*
- [ ] *Johnson & Johnson Products Inc.*
- [ ] *Odonto Corporation Ltd.*
- [X] ***Johnson & Johnson Consumer Products Co.***

Document No.: TM7024 **Franchise:** **Location:** ROYSTON, FLUID, KOLMAR

Document Type: Permanent **Expiration Date:** None

Subject: ANALYSIS OF POWDERED TALC FOR ASBESTIFORM MINERALS BY TRANSMISSION ELECTRON MICROSCOPY

1.0 SCOPE & PURPOSE

This method is applicable to the identification and quantitation of small (typically 1-20 micrometer) asbestiform minerals in powdered talc. Samples may be previously screened with light microscopy or x-ray diffraction techniques.

2.0 PRINCIPLE OF METHOD

The combined techniques of transmission electron microscopy (TEM), selected area electron diffraction (SAED) and energy dispersive x-ray analysis (EDXRA) permit the detection of asbestiform minerals based on morphological characteristics, followed by a definitive mineralogical identification of each fiber.

3.0 INTERFERENCES

Interferences are caused by fibrous particles which must be distinguished from positively identifiable asbestos, and by large particles or particle aggregates which may obscure fibers. Positively identified non-asbestos fibers include rolled talc, ribbon talc, antigorite, silica fibers and iron oxide fibers. Organic additives such as perfumes may crystallize out as fibers or needle-shaped crystals in finished cosmetic products. In the absence of positive identification, all other fibers must be classified as unidentifiable.

4.0 INSTRUMENTAL CONDITIONS

The talc specimen grids are examined in the TEM at an accelerating voltage of 120 kv and at magnification of 20,000X and 5,000X.

5.0 SENSITIVITY

This method is capable of detecting a single fiber as small as 1 micrometer (mm) long by 0.075 mm wide in the entire TEM field, which results in a theoretical detection limit of 10^{-5} weight percent. Such fibers usually can be identified readily by SAED and EDXRA. The mass of a fiber with the above dimensions is 1.1×10^{-14} g for chrysotile and 1.5×10^{-14} g for amphibole.

6.0 LIMIT OF QUANTIFIABLE DETECTION

The detection of five or more asbestiform minerals of one variety in an analysis constitutes a quantifiable level of detection. When no asbestiform minerals are detected, a representative fiber size is used to calculate a detection limit. A representative fiber size is 3 mm long by 0.2 mm wide by 0.06 mm thick, which is considerably larger than the smallest fiber that can be detected (see section 5, SENSITIVITY), but is more typical of small asbestos fibers that are detected in talc analyses. The mass of five such fibers is calculated as follows:

3 mm x 0.2 mm x 0.06 mm = $0.036 mm^3$ per fiber
x 3.3E-12 g / mm^3 = 1.2 E-13 g per fiber

Test Method

Company:

- [ ] *Personal Products Worldwide*
- [ ] *Personal Products Company*
- [ ] *Desbiens Products Inc.*
- [ ] *Johnson & Johnson Products Inc.*
- [ ] *Odonto Corporation Ltd.*
- [X] ***Johnson & Johnson Consumer Products Co.***

Document No.: TM7024 **Franchise:** **Location:** ROYSTON, FLUID, KOLMAR

Document Type: Permanent **Expiration Date:** None

Subject: ANALYSIS OF POWDERED TALC FOR ASBESTIFORM MINERALS BY TRANSMISSION ELECTRON MICROSCOPY

x 5 fibers = 6E-13 grams per 5 fibers.

The limit of quantifiable detection for most talc analyses is approximately 6 x 10^{-4} weight percent. The theoretical and quantifiable detection limits assume homogeneity of the material being sampled.

7.0 QUALITY ASSURANCE

Blank suspensions are routinely prepared and tested in order to monitor potential residual contamination from the sample jars. Blank carbon-coated grids are routinely tested to monitor the ambient fiber count. If greater than 4 fibers per grid are present, the jars are pre-cleaned or new carbon-coated grids are prepared, respective of the test.

8.0 BACKGROUND CORRECTION

As of the time of this writing, background correction has not been necessary. The amount of background asbestos detected has been insignificant in comparison to the levels of asbestos found in contaminated samples.

9.0 PREPARATION AND ANALYSIS TIME

Preparation time per sample (including preparation of related materials) is one hour. Analysis search time per sample is a maximum of two hours.

10.0 APPARATUS

10.1 Analytical balance with 0.0001 gram sensitivity

10.2 Weighing boats

10.3 Narrow spatula

10.4 Wide mouth polyethylene jars (125 ml)

10.5 Mild ultrasonic bath, minimum 50 watts

10.6 Micropipettor (5-10 ml range) with disposable tips

10.7 Standard 3 mm diameter, 200 mesh, copper TEM grids, covered with a carbon-coated formvar film.

10.8 Transmission electron microscope (TEM) with an 80-120 kv accelerating voltage and energy dispersive x-ray analyzer.

Test Method

Company:

- [ ] *Personal Products Worldwide*
- [ ] *Personal Products Company*
- [ ] *Desbiens Products Inc.*
- [ ] *Johnson & Johnson Products Inc.*
- [ ] *Odonto Corporation Ltd.*
- [X] ***Johnson & Johnson Consumer Products Co.***

Document No.: TM7024 **Franchise:** **Location:** ROYSTON, FLUID, KOLMAR

Document Type: Permanent **Expiration Date:** None

Subject: ANALYSIS OF POWDERED TALC FOR ASBESTIFORM MINERALS BY TRANSMISSION ELECTRON MICROSCOPY

11.0 REAGENTS

11.1 Methyl cellulose, powder, USP 4000 cps - Fisher Certified Reagent #M-352 or equivalent

11.2 Water: deionized, particle free (+0.2 mm filtered)

11.3 Methyl cellulose solution: 0.002% (wt/vl) (20 ppm). Dissolve 20 % 0.5 mg of methyl cellulose in 500 ml of deionized particle free water to make a 0.004% stock solution. Dilute 1:1 to make a working solution.

NOTE: Methyl cellulose acts as a wetting agent to aid in maintaining a uniform particle distribution as the sample dries, by greatly reducing the surface tension of water.

12.0 SAMPLE PREPARATION

12.1 Transfer 30 to 50 mg of talc powder to a clean 125 ml polyethylene jar.

12.2 Add 80 ml of 20 ppm methyl cellulose solution, cap and shake vigorously for one minute.

12.3 After shaking, loosen cap and ultrasonicate for 10 minutes in order to disperse the finer particles. Then shake again for one minute to produce a uniform suspension.

12.4 Immediately after shaking, uncap and remove 9.2 microliters with a micropipette.

12.5 Transfer a 9 ml drop to a carbon film covered TEM grid. (Grid was first lightly anchored by 2 parallel strips of double-stick tape mounted 3 mm apart on a clean glass microscope slide.) Repeat to make two sample grids per talc sample.

NOTE: Do not expel the remaining 0.2 ml suspension from the micropipette tip. It tends to sputter and frequently destroys the stability of the sample drop.

12.6 Transfer slide with grids to a desiccator. (Drying time is 2-3 hours.) Do not leave the grids on the slide for more than one day as the double-stick tape may adhere too tightly.

NOTE: The talc:water ratio may need to be varied for some samples. Preparation of talc samples with a significantly finer or coarser particle size results in large differences in particle coverage on the TEM grid.

Test Method

Company:

- [ ] *Personal Products Worldwide*
- [ ] *Personal Products Company*
- [ ] *Desbiens Products Inc.*
- [ ] *Johnson & Johnson Products Inc.*
- [ ] *Odonto Corporation Ltd.*
- [X] ***Johnson & Johnson Consumer Products Co.***

Document No.: TM7024 **Franchise:** **Location:** ROYSTON, FLUID, KOLMAR

Document Type: Permanent **Expiration Date:** None

Subject: ANALYSIS OF POWDERED TALC FOR ASBESTIFORM MINERALS BY TRANSMISSION ELECTRON MICROSCOPY

13.0 TEM ANALYSIS

13.1 Definition of fiber: An elongated particle with parallel sides and an aspect ratio K3:1. The definition employed may vary with the needs of the client.

13.2 Scan sample at 120-150X magnification to check for even dispersion of particles and to locate grid squares with optimum particle density. (Optimum particle density is particle coverage over 15-35% of the field of view.)

13.3 Scan three grid squares on each grid at 20,000X magnification and seven grid squares on each grid at 5,000X for asbestiform minerals. Each asbestiform mineral is recorded as to type (chrysotile, tremolite, anthophyllite, etc.), structure (bundle, clump, fiber) and dimensions (length x width).

13.4 Questionable fibers are examined first by SAED. The chrysotile SAED pattern is unique and diagnostic. Amphibole SAED patterns are variable but usually characteristic. Additional analysis and measurement of amphibole SAED patterns are done if warranted.

13.5 Ten percent of chrysotile fibers are checked by EDXRA for further confirmation. If the SAED pattern is not clearly diagnostic, or if it is consistent with an amphibole SAED pattern, then it is examined by EDXRA to confirm the identification or to identify the type of amphibole.

14.0 CALCULATION OF RESULTS

14.1 Mass of chrysotile fibers: M(f)

$M(f) = \pi r^2 l \times d$

$\pi = 3.14159$

r = fiber radius

l = fiber length

d = density of chrysotile = 2.55×10^{-12} g/mm^3

14.2 Mass of asbestiform amphibole particles: M(a)

M(a) = l x w x th x d

l = length

w = width

th = thickness Z 0.3 width (approximation)

d = density of amphiboles = 3.3×10^{-13} g/mm^3

14.3 Mass of talc deposited on each TEM grid: M(s)

M(s) = T x (V/H)

T = amount of talc sampled (step 12.1)

V = volume of aliquot transferred to TEM grid (step 12.5)

Test Method

Company:

- [ ] *Personal Products Worldwide*
- [ ] *Personal Products Company*
- [ ] *Desbiens Products Inc.*
- [ ] *Johnson & Johnson Products Inc.*
- [ ] *Odonto Corporation Ltd.*
- [X] ***Johnson & Johnson Consumer Products Co.***

Document No.: TM7024 **Franchise:** **Location:** ROYSTON, FLUID, KOLMAR

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H = volume of methyl cellulose solution (step 12.2)

14.4 Total estimated talc mass examined: M(t)

M(t) = M(s) x (N x A(s))/A(g)

N = number of grid squares examined

A(s) = area of a single TEM grid square

A(g) = area of an entire TEM grid (effective area over which a 9 microliter drop of suspension dries)

14.5 Weight percent:

$$\frac{\text{sum total of M(f) or M(a) x 100}}{\text{M(t)}}$$

15.0 CALCULATION OF A DETECTION LIMIT

15.1 M(dl) = A minimum quantifiable mass of asbestos fibers, based on the detection of 5 fibers (approximately 6E-13 grams, from Section 6).

15.2 Detection Limit (Weight Percent) = $\frac{\text{M(dl) x 100}}{\text{M(t)}}$

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Exhibit 60

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION IX

Response to the November 2005 National Stone, Sand & Gravel Association Report Prepared by the R.J. Lee Group, Inc "Evaluation of EPA's Analytical Data from the El Dorado Hills Asbestos Evaluation Project"

April 20, 2006

United States Environmental Protection Agency Region 9
Response to the November 2005 National Stone, Sand & Gravel Association report prepared by the R.J. Lee Group, Inc:
"Evaluation of EPA's Analytical Data from the El Dorado Hills Asbestos Evaluation Project"

This document constitutes the United States Environmental Protection Agency Region 9 (EPA Region 9) response to the major findings and conclusions of the National Stone, Sand & Gravel Association report "Evaluation of EPA's Analytical Data from the El Dorado Hills Asbestos Evaluation Project" prepared by the R. J. Lee Group (R. J. Lee Report). A more detailed analysis will be completed after additional information is received from the R. J. Lee Group and the National Stone, Sand & Gravel Association,[1] and the United States Geological Survey (USGS).

The R. J. Lee Report draws conclusions that are contradicted by the El Dorado Hills data and by generally accepted scientific principles for measuring asbestos exposure.

Overview

The R. J. Lee Group review of the EPA data was contracted by the National Stone, Sand & Gravel Association. The El Dorado County Office of Education funded the three reviewers who wrote letters in support of the R. J. Lee Report and whose reviews are included in this response.

The EPA Region 9 El Dorado Hills Naturally Occurring Asbestos Exposure Assessment was designed to measure the exposures to asbestos fibers, if any, that resulted from sports and play activities that disturbed dust and soil. EPA Region 9 adhered to accepted EPA standards for sampling and analysis, including rigorous quality assurance/quality control, and to the standard methodologies of EPA exposure and risk assessment.

The R. J. Lee Report Criticizes EPA Region 9 for Using Established Scientific and Public Health Protocols - In assessing naturally occurring asbestos exposures in El Dorado Hills, EPA evaluated asbestos exposures using the PCME (phase contrast microscopy equivalent) asbestos fiber size classification. The PCME classification was used because human epidemiological studies, which form the basis of knowledge of asbestos health effects, measured asbestos fiber concentrations using phase contrast microscopy (PCM) analytical methods. PCME is the standard term for fibers counted by more modern analytical methods that are of equivalent size to those fibers that would be seen by PCM analysis, and includes fibers with a length to width aspect ratio of 3 to 1 or greater. EPA considered PCME fibers in our analysis of the El Dorado data to be consistent with the existing health databases and risk assessment

[1]On March 9, 2006, EPA Region 9 sent a letter to the R.J. Lee Group and the National Stone, Sand, & Gravel Association asking for additional information to support the findings and conclusions of the R.J. Lee Report.

procedures used by EPA, California EPA (Cal/EPA), the World Health Organization, and other federal agencies and international organizations. This approach was rejected by the R.J. Lee Group, which instead advocates use of asbestos fiber definitions which are not health based or supported by the majority of experts in the health community, and which would not allow comparison to the existing epidemiologic data on asbestos related cancers.

The R. J. Lee Report Claims that EPA Region 9 Misapplied Fiber Counting Protocols - The R. J. Lee Report claims that EPA Region 9 inflated the fiber counts in the El Dorado Hills air data by misapplying the International Standards Organization (ISO) method 10312 (the analytical method used by EPA to analyze the El Dorado air samples) and including PCME structures with a 3 to 1 length to width aspect ratio in our analysis. The R. J. Lee Report maintains that EPA should only have counted structures which met the general 5 to 1 aspect ratio fiber size definition described in the body of the ISO 10312 method. However, Annex C and Annex E of the ISO 10312 method specifically authorize the counting of PCME structures with a 3 to 1 aspect ratio. Another example of misleading information is the R.J. Lee Report's statistical evaluation and resulting conclusions regarding the concentrations of asbestos structures detected in the EPA air samples. All of the established EPA, National Institute of Occupational Safety and Health (NIOSH), and ISO analytical methods require the counting of asbestos bundles, recognizing the significance of bundles to proper characterization of asbestos fiber levels. The R.J. Lee Report did not include asbestos bundles in its analysis of the data, thereby undercounting the number of structures.

The R. J. Lee Report Claims that EPA Region 9 Misidentified Amphibole Minerals - The R. J. Lee Report concludes that EPA misidentified actinolite asbestos fibers in the El Dorado soil samples by using inappropriate extinction angle criteria. The R. J. Lee Group conclusion is contradicted by the National Institute of Standards and Technology (NIST) and the major analytical methods used for analysis of asbestos in soil and bulk samples. The R. J. Lee Report also cites an unpublished 1980 draft report to support its contention that structures found in the EPA air samples are not asbestos, and ignores a subsequent 1981 published report by the same author that actually supports the EPA approach.

The R. J. Lee Report Applies a Geologic Definition rather than a Public Health Definition to Characterize Microscopic Structures - The R. J. Lee Report relies heavily on the geologic distinction between asbestos fibers and cleavage fragments of the same dimensions, with the implication that exposure to cleavage fragments is benign and of little or no health significance. For the purposes of public health assessment and protection, EPA makes no distinction between fibers and cleavage fragments of comparable chemical composition, size, and shape. The EPA Region 9 approach, which is supported by most public health agencies and scientists, as well as the American Thoracic Society, is based on the following: (1) The epidemiologic and health studies underlying EPA and Cal/EPA cancer risk assessment methods were based on exposures to both cleavage fragments and fibers, and were unable to distinguish between the two, (2) The most recent panel of experts to review asbestos risk assessment methods, the 2003 Peer Consultation Panel convened by EPA, concluded that "it is prudent at

this time to conclude equivalent potency [of cleavage fragments and fibers] for cancer,"[2] (3) No well-designed animal or epidemiological studies have adequately tested the hypothesis that cleavage fragments with the same dimensions as a fiber are benign or that the human body makes any distinction, (4) Studies that purport to show that cleavage fragments are benign are questioned by many asbestos health experts, (5) There are no routine asbestos air analytical methods, including those used by EPA, NIOSH, the Mine Safety and Health Administration (MSHA), the American Society for Testing and Materials (ASTM), and ISO which differentiate between cleavage fragments and crystalline fibers on an individual fiber basis.

The R. J. Lee Report's "Virtual" Review of EPA Region 9's Air Samples is Inconsistent with Established Laboratory Practices - The R.J. Lee Group did not have access to EPA's actual air samples, nor did it collect any air samples of its own. Rather it reviewed limited pictures and spectra data of a small number of EPA's air samples and drew conclusions based on those representations. Such a virtual review is not consistent with the National Voluntary Laboratory Assurance Program (NVLAP) quality assurance procedures nor the verification methods of the National Institutes of Standards and Technology.

Federal Courts Have Supported EPA - Many of the assertions of the R. J. Lee Report are consistent with positions that the R.J. Lee Group took as an expert witness for W.R. Grace in the Libby, Montana litigation. In this litigation, the written opinions of the District and Appeals courts, while not specifically addressing the opinions of the R.J. Lee Group, rule in favor of EPA and expressly hold that EPA's experts and science are credible.[3]

Background

In October 2004, the EPA Region 9 Superfund site assessment program conducted an assessment of exposures to naturally occurring asbestos (NOA) in El Dorado Hills, California. Specifically, EPA Region 9 simulated the sports activities of children and adults at three schools and a community park and, using personal air monitors, measured asbestos levels in the breathing zones of participants. EPA Region 9 also collected samples of ambient air in the area of the sampling at the same time the simulations were conducted to serve as reference samples. The personal activity-based samples were then compared to the reference samples. The Asbestos Hazard Emergency Response Act (AHERA)[4] regulation Z-test for statistical

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[2]USEPA (U.S. Environmental Protection Agency) (2003). Report on the Peer Consultation Workshop to Discuss a Proposed Protocol to Assess Asbestos-Related Risk, Final Report. Office of Solid Waste and Emergency Response, Washington D.C. Page viii.

[3] See U.S. v. W.R. Grace, 280 F Supp 2d 1149 (2003): U.S. v. W.R. Grace, 429 F. 3d 1224, 1245 (9th Cir. 2005) (Although debate regarding testing methodology and data analysis is "exceedingly complex", EPA did not ignore accepted scientific principles)

[4]The Asbestos Hazard Emergency Response Act (AHERA) was passed by Congress in 1986 to provide for the inspection and mitigation of asbestos in school buildings. Regulations implementing the Act were promulgated by EPA in 1987.

significance was applied to determine whether there were any statistically significant differences between the personal exposure samples and the ambient reference samples. EPA Region 9 collected over 400 air samples and generated over 7000 data points. All of EPA Region 9's's analyses were conducted by accredited laboratories using recognized methods and procedures with strict quality assurance control, including blind performance samples to check analytical accuracy.

Amphibole asbestos, which many health scientists consider to be even more toxic than chrysotile asbestos, was found in almost all the reference and activity-based samples. Of the 29 different sets of activity-based scenario measurements, application of the Z-test determined that personal exposures from 24 scenarios were significantly elevated over the reference samples. Most importantly, the data showed that children and adults participating in sports activities in areas where asbestos occurs naturally in the surface soils, as it does in El Dorado Hills, can be exposed to asbestos fibers of health concern at up to 62 times the corresponding reference levels.

EPA Region 9 released the data from the assessment in May 2005 and held a public meeting in El Dorado Hills that was attended by more than 1000 members of the public. From the outset of the assessment, EPA Region 9 made clear to the community that EPA's only intent was to gather data on potential exposures. The community and the State and local regulatory agencies could then use the information to make decisions about the significance of those exposures and determine appropriate control measures. Both EPA Region 9 and the Agency for Toxic Substances and Disease Registry (ATSDR) have informed the community that exposure levels are a main determinant of the risk of developing asbestos-related cancers and non-cancer diseases, and that reducing the exposures reduces the risk. Consistent with its intent, EPA Region 9 has actively engaged the State and local regulatory agencies to improve naturally occurring asbestos mapping, monitoring, dust control, and regulation. El Dorado County has recently adopted more stringent dust control ordinances.

Detailed Comments on the R. J. Lee Report

R.J. Lee Finding #1: "Based on Mineralogy, Sixty-Three Percent (63%) of the Amphibole Particles Identified as Asbestos Fibers can not be Asbestos."

The R. J. Lee Report argues that there is too much aluminum in 63% of EPA Region 9's identified fibers for the fibers to be asbestiform.[5] In addition, the remaining 37% (sometimes the Report uses 35%) are not asbestos fibers based on their particle dimensions.

EPA Response

Aluminum - Analysis of the EPA Region 9 El Dorado air samples was performed using the International Standards Organization (ISO) method 10312, a state-of-the-art

[5]Asbestiform: Having the form or structure of asbestos.

Transmission Electron Microscope (TEM)[6] method with energy dispersive spectroscopy (EDS)[7] that has strict counting rules and characterizes the dimensions and chemistry of every fiber identified by the microscopist. Identification of fiber type was performed according to the general guidelines of the International Mineralogical Association (IMA) (Leake, 1997)[8], the international standard for amphibole nomenclature. This same approach for asbestos classification is recommended in the "Research Method for Sampling and Analysis of Fibrous Amphibole in Vermiculite Attic Insulation", EPA 600/R-04/004, January 2004, and was one of the tools used by Meeker et al (2003)[9] to determine the composition and morphology of amphiboles from Libby, Montana.

The R. J. Lee Report claims that 63% of the amphibole fibers identified by the EPA laboratory[10] as actinolite asbestos have concentrations of total aluminum that are too high to form asbestos fibers. According to page 2 of the R. J. Lee Report, "Particles with more than 0.3 aluminum atoms pfu [per formula unit] or about 1.5 percent Al_2O_3 cannot form in the asbestos habit due to crystal lattice constraints." To support its argument, the R. J. Lee Report cites three references. However, on close examination, two of the three references do not agree with the upper threshold limit that the R.J. Lee Group puts on total aluminum content (Leake et al, 1997) (Deer, Howie and Zussman, 1997)[11]. The third reference (Verkouteren & Wylie, 2000)[12] draws its conclusions on examination of a

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[6]Transmission Electron Microscopy (TEM) produces images of a sample by illuminating the sample with an electron beam in a vacuum, and detecting the electrons that are transmitted through the sample.

[7]Energy Dispersive Spectroscopy (EDS) uses measurement of the energy and intensity of X-rays generated when a selected area of a sample is irradiated with an electron beam to identify the mineralogical composition of a structure.

[8]B.E. Leake et al (1997). Nomenclature of Amphibole: Report of the Subcommittee on Amphiboles of the International Mineralogical Association, Commission on New Minerals and Mineral Names. American Mineralogist, Volume 82, pages 1019-1037.

[9]G.P. Meeker et al (2003). The Composition and Morphology of Amphiboles from the Rainy Creek Complex, Near Libby, Montana. American Mineralogist, Volume 88, pages 1955-1969.

[10]In this document, the terms "EPA laboratory" and "EPA Region 9 laboratory" refer to the private laboratories that conducted the analysis of the EPA soil and air samples under contract to EPA Region 9.

[11]W.A. Deer, R.A. Howie, and J. Zussman (1997). Rock-Forming Minerals: Double Chain Silicates, Vol 2, second edition, p 137 - 145.

[12]J.R. Verkouteren and A.G. Wylie (2000). The Tremolite-Actinolite-Ferro-Actinolite Aeries: Systematic Relationships Among Cell Parameters, Composition, Optical Properties, and

small set of fibrous actinolite asbestos samples which the authors partition into asbestos and fibrous "non-asbestos" byssolite using criteria which the IMA specifically recommends against, and which is inconsistent with all standard asbestos analytical methods. Perhaps most important is the fact that all three references agree that it is the IMA criteria which primarily govern the general classification of amphibole type, not the total aluminum content. These references therefore actually support the classification approach taken by the EPA laboratory.

The R.J. Lee Group did not have access to the EPA air samples to conduct their own analyses. Instead, the R.J. Lee Group looked at a limited number of photographs of the recorded EDS spectra. Interferences by other elements in the sample can affect the aluminum total in the spectra. This is especially important because the EPA samples were of air releases from soil, not processed asbestos material. Soils contain non-asbestos mineral and biological particles that can influence element totals in an EDS spectrum, most notably clay particles, which are high in aluminum. The laboratory used by EPA Region 9 identified aluminum-rich actinolite asbestos, by applying the IMA classification guidelines to its direct analysis of the actual sample.[13]

Particle Dimension - As previously stated, the R. J. Lee Report claims that 37% of the fibers counted by EPA in the El Dorado Hills air samples are not asbestos fibers based on their particle dimensions. The report claims that EPA Region 9 inflated the fiber counts by including asbestos structures which do not meet the definition of a fiber as described in ISO 10312. The general ISO 10312 method requires the counting of every asbestos structure with a length to width aspect ratio of 5:1 or greater. As directed by Region 9, the EPA laboratory counted structures with a 3:1 or greater aspect ratio. The R. J. Lee Report states that EPA erred in counting structures with aspect ratios less than 5:1. **Annex C and Annex E of the ISO method clearly authorize the counting of PCME structures with a 3:1 aspect ratio if the data are to be used for exposure or risk assessment purposes, the stated goal of the El Dorado Hills assessment. In fact, the ISO method contains numerous references to PCME fibers. PCME fibers are defined as fibers greater than 5 microns in length, and 0.25 to 3 microns in width with a 3:1 aspect ratio.[14] PCME fibers form the basis for EPA's IRIS toxicity database and the asbestos risk models of California EPA and other federal and international organizations.[15]**

Habit, and Evidence of Discontinuities. American Mineralogist, 85, p. 1239 - 1254.

[13]Personal communication with John Harris, Lab/Cor, January 2006.

[14]World Health Organization (1986). Environmental Health Criteria 53, International Programme on Chemical Safety, Asbestos and Other Natural Mineral Fibres, section 2.3.2.2.

[15]The IRIS asbestos cancer inhalation unit risk, a measure of asbestos cancer potency, is based on the EPA 1986 Airborne Asbestos Health Assessment Update (EPA/600/8-84/003F; 1986). Cal/EPA used a similar approach and data sets to derive its cancer unit risk. Both the IRIS and the Cal/EPA cancer potency values rely on human epidemiological studies that were conducted using phase contrast microscopy (PCM) analytical methods (some were midget

The R.J. Lee Group also manipulates its statistical analysis of the El Dorado Hills air data by ignoring counts of asbestos fiber bundles in its evaluations. Bundles are two or more attached parallel asbestos fibers which can have a significant health impact when they are inhaled and separate into individual fibers. Bundles were counted in the historical epidemiological studies which form the basis of our knowledge of asbestos-related health effects and EPA's IRIS database. **All of the established EPA, NIOSH, and ISO analytical methods require the counting of asbestos bundles, recognizing the significance of bundles to proper characterization of asbestos fiber levels.**

The R. J. Lee Report further states that EPA's data inflated the asbestos fiber count by ignoring the Agency's own "definition" of asbestos. To support this claim, the R.J. Lee Report cites the glossary of "Method for Determination of Asbestos in Bulk Building Materials", EPA 600/R-93/116, 1993, which states, in part, "With the light microscope, the asbestiform habit is generally recognized by the following characteristics: Mean aspect ratios ranging from 20:1 to 100:1 or higher for fibers longer than 5 microns." The building material analytical method is designed to detect commercially processed asbestos in items like floor tiles, roofing felts, paper insulation, paints, and mastics, not naturally occurring asbestos on air filters or in soil samples. To present the 20:1 aspect ratio for commercial grade asbestos as a universal EPA policy, and to advocate its use as an appropriate standard for analyzing air samples of naturally occurring asbestos is inappropriate and contradictory to use of the PCME dimensional criteria as a tool for assessing exposure risk.

The R. J. Lee Report also states that the diffraction pattern analyses produced by the EPA laboratory for the El Dorado Hills air samples demonstrates that the particles identified by the laboratory are not asbestos.[16] The report cites a 1980 unpublished draft study by S.J. Ring to support its conclusion. The R. J. Lee Report does not mention a 1981 published article by the same author which revises the findings such that they no longer support the conclusion of the R. J. Lee Report and, in fact, support the data produced by

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impinger data converted to PCM counts) that could not distinguish fibers that were 5 microns in length or less. PCM cannot distinguish between fibers and cleavage fragments. PCM is not as powerful as current Transmission Electron Microscope (TEM) methods (400X vs 20,000X) as TEM can see the thinner/shorter fibers. However, since EPA's (and Cal/EPA 's) toxicity database relies on human health studies that used PCM, current EPA risk procedures use the more powerful TEM method but report the PCM equivalent (PCME) fibers and only use the PCME counted fibers in a risk assessment. This is because the IRIS asbestos file specifies that only PCME fiber counts be used with inhalation unit risk for risk calculation. See also the reference cited in footnote 11.

[16]Diffraction pattern analyses irradiates a sample with x-rays and then takes an x-ray photograph.

EPA.[17]

R.J. Lee Finding #2: "The Laboratory Procedures did not Comply With the NVLAP Quality Assurance Standard."

The R. J. Lee Report says that the false positive rate in our air samples was 35% when the acceptable limit in the National Voluntary Laboratory Accreditation Program (NVLAP) is 10%.

EPA Response

The laboratories used by EPA Region 9 for analysis of the El Dorado Hills air and soil samples are accredited through the National Voluntary Laboratory Accreditation Program (NVLAP). NVLAP is administered by the National Institute of Standards and Technology, a non-regulatory agency within the U.S. Commerce Department. A large part of the accreditation process involves on-site audits performed by NVLAP-certified inspectors who review laboratory operational and quality assurance compliance parameters, including documentation proving compliance with NVLAP requirements for verification analyses. A laboratory must demonstrate that all analysts reporting data meet the false negative and false positive requirements set forth by NVLAP before an accreditation certificate is issued. To make a determination that a laboratory did not comply with NVLAP verification standards would require a very detailed examination of all laboratory generated raw data, project specific information, such as a site-specific EPA issued Quality Assurance Project Plan, laboratory instrument log books, and other data and information not supplied in an analytical report. Interviews with the laboratory manager, quality assurance manager, and involved analysts are also mandatory to make judgement on a laboratory's possible non-compliance. The R.J. Lee Report's conclusion that the EPA laboratory was not in compliance with NVLAP, based on a cursory review of count sheet and other limited data without the in-depth examination detailed above, is therefore invalid and cannot be used to question EPA's analytical results.

EPA chose NVLAP-accredited laboratories for the El Dorado Hills assessment as a minimum quality requirement. For supplemental quality assurance, the laboratories were subjected to on-site audits performed by EPA's Quality Assurance Technical Support group, and both laboratories were sent performance evaluation samples prior to analysis of the El Dorado samples. In addition, the laboratory conducting the air sample analysis was sent double blind performance evaluation samples during the sampling event. In all cases, the laboratories successfully identified the amounts and types of asbestos present on the blind samples within acceptable limits. Further, the El Dorado Hills air and soil data were validated by a third party in accordance with standard EPA quality assurance

[17]S.J. Ring (1981). Identification of Amphibole Fibers, Including Asbestos, Using Common Electron Diffraction Patterns. In Russell P.A. and Hutchings A.E. (Eds), Electron Microscopy and X-ray Applications to Environmental and Occupational Health Analysis, Vol. 2:175-198, Ann Arbor Science Publ., Inc.

procedures and were found to be acceptable for all uses.

R. J. Lee Finding #3: "The Soil Samples do not Demonstrate the Presence of Amphibole Asbestiform Minerals."

The R. J. Lee Report states that the actinolite asbestos fibers identified in the El Dorado Hills soil samples contain too much aluminum to be asbestiform and that the extinction angles of the fibers indicate that they are non-fibrous cleavage fragments. The R.J. Lee Group's analysis of 23 split soil samples from EPA's October 2004 sampling event found no asbestos in the samples.

EPA Response

Aluminum - The R. J. Lee Report states that the aluminum content of the fibers in the soil samples was too high to be asbestiform actinolite and that it was indicative of non-asbestiform actinolite and another amphibole, hornblende, which contains approximately 10-20% by weight Al_2O_3 (5.3-10.6% by weight aluminum). Both the laboratory performing EPA's El Dorado soil sample analysis and the laboratory which analyzed the EPA air samples noted significant quantities of hornblende in the samples, but did not count or report those particles as asbestos. Please see the EPA response to Finding #1 for a further discussion of the aluminum issue.

Extinction Angles - The extinction angle of a fiber evaluated by polarized light microscopy is one of many criteria used to identify mineralogical composition. The extinction angle for amphibole asbestos fibers is the difference in degrees between the long axis of the fiber and the angle at which the fiber optically disappears (the polarization direction where the light passing through it becomes "extinct") when the fiber is rotated under a polarized light microscope. The R.J. Lee Report states that amphibole asbestos fibers have a zero-degree extinction angle and that non-asbestos cleavage fragments have non-zero extinction angles. Therefore, because the EPA soil sample analysis reported extinction angles which, according to the R.J. Lee Group, averaged 12°, the report alleges EPA incorrectly identified cleavage fragments as asbestos fibers.

The R.J. Lee Report's conclusion regarding extinction angles is contradicted by the National Institute of Standards and Technology (NIST) and the major analytical methods used for analysis of asbestos in soil and bulk samples. NIST certifies and provides Standard Reference Materials (SRM) for laboratory instrument calibration and laboratory accuracy measurement. The NIST Tremolite/Actinolite SRM 1867A is a special set of three samples certified by NIST to be of ultra-high purity tremolite, actinolite, and anthophyllite asbestos and is considered the "gold standard" for asbestos analytical laboratories. The material is rigorously characterized and is accompanied by a six-page document that describes the properties of each sample. It is required that all analytical laboratories accredited by NIST/NVLAP have the material in their possession and that they use it to calibrate their operations and to test their analysts. The NIST SRM

1867A certificate which accompanies the samples of tremolite and actinolite states that the reference tremolite can have an extinction angle of up to 16.6 ± 0.3° and that the actinolite can have an extinction angle of up to 15.9±0.2°. When the EPA laboratory processed the NIST actinolite standard in the manner of the El Dorado Hills soil samples, the extinction angles of the fibers in the processed standard sample were consistent with allowed maximum extinction angles for tremolite/actinolite asbestos (~ 10° to 20°) and the extinction angles of the fibers seen in the EPA soil samples.[18]

Further, the laboratory methods of EPA, NIOSH, and other agencies for analysis of asbestos in bulk material all state that tremolite-actinolite asbestos fibers may have zero (parallel) or *non-zero* (inclined or oblique) extinction angles. EPA Method 600/R-93/116[19], the standard method used by all NIST/NVLAP accredited laboratories to test building materials for the presence of asbestos, states in Table 2-2, Optical Properties of Asbestos Fibers, that tremolite-actinolite asbestos has extinction "parallel and oblique (up to 21°)." NIOSH Method 9002[20], the method used for analysis of the El Dorado Hills soil samples, states directly that actinolite and tremolite fibers exhibiting inclined extinction are to be considered asbestos. The method further states that "If anisotropic fibers are found (during PLM analysis), rotate the stage to determine the angle of extinction. Except for tremolite-actinolite asbestos which has oblique extinction at 10-20°, the other forms of asbestos exhibit parallel extinction... Tremolite may show both parallel and oblique extinction."[21]

R.J. Lee Finding #4: "The ISO 10312 Analytical Method can not Distinguish Between Asbestos Fibers and Non-Asbestos Cleavage Fragments."

The R.J. Lee Report states that the ISO 10312 method contains the disclaimer that "The method cannot discriminate between individual fibers of asbestos and non-asbestos analogues of the same amphibole material," and, therefore, EPA inflated the asbestos air concentrations by counting "cleavage fragments."

EPA Response

The ISO 10312 method cannot differentiate between fibers and cleavage fragments with

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[18]M. Bailey (2006). Identification of Asbestiform Tremolite/Actinolite. Naturally Occurring Asbestos Workgroup Meeting Presentation.

[19]USEPA (U.S. Environmental Protection Agency) (1993). Method for the Determination of Asbestos if Bulk Building Materials. EPA Method 600/R-93/116.

[20]NIOSH (National Institute for Occupational Safety and Health) (1992). Asbestos (Bulk) by PLM.. Method 9002 (Issue 2).

[21]NIOSH (National Institute for Occupational Safety and Health) (1992). Asbestos (Bulk) by PLM.. Method 9002 (Issue 2). Qualitative Assessment, Item c, page 4.

the same dimensions and chemical composition. No routine analytical method has a protocol for distinguishing fibers from cleavage fragments on an individual particle basis. Additionally, from a health standpoint, there is no evidence that supports making the distinction.

Cleavage fragment is a geologic term which refers to structures that form when non-fibrous forms of asbestos minerals split along crystallographic planes, as opposed to asbestos fibers which form from crystalline growth. The R.J. Lee Report maintains that there is a toxicological difference between asbestos structures which formed as fiber crystals and fibers which formed by cleavage plane separation. Page 3 of the R.J. Lee Report states that cleavage fragments are "not known to produce asbestos-like disease." **It is the position of EPA, the U.S. Centers for Disease Control and Prevention, Agency for Toxic Substances and Disease Registry (ATSDR) and National Institute for Occupational Safety and Health (NIOSH), and the American Thoracic Society, among others, that microscopic structures of amphibole and serpentine minerals that are asbestiform and meet the size definition of PCM fibers, should be counted as asbestos, regardless of the manner by which they were formed.** There are four reasons why the health agencies have taken this position: (1) The epidemiologic and health studies underlying EPA, and California EPA, cancer risk assessment methods were based on exposures to both cleavage fragments and fibers, but were unable to distinguish between the two, (2) The most recent panel of experts to review asbestos risk assessment methods, the 2003 Peer Consultation Panel convened by EPA, concluded that "it is prudent at this time to conclude equivalent potency [of cleavage fragments and fibers] for cancer,"[22] (3) No well-designed animal or human epidemiological studies have been conducted to date to test the hypothesis that cleavage fragments with the same dimensions of a fiber are benign, or that the human body makes any distinction, and studies that purport to show that cleavage fragments are benign are questioned by many asbestos health experts,[23] (4) There are no routine air analytical methods, including those used by EPA, NIOSH, the Mine Safety and Health Administration (MSHA), the American Society for Testing and Materials (ASTM), and the ISO which differentiate between cleavage fragments and crystalline fibers.

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[22]USEPA (U.S. Environmental Protection Agency) (2003). Report on the Peer Consultation Workshop to Discuss a Proposed Protocol to Assess Asbestos-Related Risk, Final Report. Office of Solid Waste and Emergency Response, Washington D.C. Page viii.

[23]Both Addison (Addison J, Davies LST. 1990. Analysis of amphibole asbestos in chrysotile and other minerals. Ann Occ Hyg, Apr;34(2):159-75) and members of the U.S. EPA 2003 Peer Consultation panel raised concerns about interpretation of the Davis study (Davis JM, McIntosh C, Miller BG, Niven K. 1991. Variations in the carcinogenicity of tremolite dust samples of differing morphology. Ann NY Acad Sci, Dec;643:473-90), which attempted to compare the toxicity of asbestos fibers and cleavage fragments. These concerns reflected the lack of peer review, use of intra peritoneal injection instead of inhalation exposure, significance of mesotheliomas caused by structures reported as cleavage fragments, purity of the cleavage fragment samples and issues related to fiber dimensions.

In terms of epidemiological data and health outcomes, the cleavage fragment argument is without merit. For the purposes of public health assessment and protection, EPA makes no distinction between fibers and cleavage fragments of comparable chemical composition, size, and shape.

There are no recognized analytical protocols, including those used by EPA, NIOSH, MSHA, ASTM, and ISO, which include criteria to differentiate between cleavage fragments and crystalline fibers. All these methods require that structures which meet their definition of the specific counting rules for an asbestos fiber be counted. The requirements are based on the fact that, in the words of an expert from the United States Geological Survey, "At a microscopic level, distinguishing between these forms on single [asbestos] particles, can be extremely difficult to impossible."[24] As noted above, R.J. Lee made a very similar claim with regard to cleavage fragments as the expert witness for W.R. Grace in the Libby, Montana, Superfund cost recovery litigation. The EPA analytical experts who reviewed the R.J. Lee Group's testing methodology related to the Libby site found that the R.J. Lee laboratory could not demonstrate any reliable criteria with which to distinguish, at the microscopic level, asbestos cleavage fragments from asbestos fibers of the same size, shape, and composition. The Ninth Circuit Court of Appeals recognized the competing scientific arguments but found that EPA's position was consistent with the record of evidence and accepted scientific principles.[25]

R.J. Lee Finding #5: "Applying the Latest Science and Definitional Techniques, the El Dorado Hills Study Shows no Significant Exposure to the Type of Amphibole Asbestos Fiber Connected To Health Risk."

The R. J. Lee Report claims that the latest science for measuring the risk posed by asbestos is the Berman-Crump Asbestos Risk Assessment Protocol ("Berman-Crump") which proposes that amphibole asbestos fibers which are more than 10 microns long and less than 0.5 microns wide (protocol fibers) are the most toxic. Of the 2,386 fibers which the R. J. Lee Report states the EPA laboratory identified, the R.J. Lee Report concludes that only 7 fibers meet the "Berman-Crump" definition. Therefore, the R.J. Lee Group maintains that EPA has overstated the risk from exposure to asbestos fibers in El Dorado Hills.

EPA Response

The "Berman-Crump" protocol that the R.J. Lee Report references is in fact a draft EPA method. EPA had the method reviewed by a peer consultation panel in 2003. The panel made a number of important recommendations that must be addressed before the method can be used for EPA risk assessments. A number of important revisions have been made

[24]G.P. Meeker, USGS, (2002). Review of Expert Report of R.J. Lee.

[25]U.S. v. W.R. Grace, 429 F.3d at 1245.

to the draft method since 2003, but at this time the method has not been independently peer reviewed. It will not be adopted by EPA as a risk assessment tool unless and until it passes rigorous internal and external peer review.

The expert peer panel has recommended that the fiber size for the draft EPA risk assessment method be adjusted to include fibers greater than 5 microns in length and up to 1.5 microns in width.[26] The change is designed to account for lung deposition of fibers that results when fibers are inhaled through the mouth, and not filtered by the nasal passages. The broadening of the fiber definition to include inhalation by "mouth breathers" is especially relevant to the El Dorado Hills data. Our investigation measured personal asbestos exposures of individuals participating in sports activities, where physical exertion would likely increase breathing through the mouth. **The PCME fibers counted in the EPA air samples are actually consistent with the latest science of EPA, as reflected in the recommendations of the peer consultation panel.** In addition, the EPA peer consultation expert panel recommended that cleavage fragments be treated as any other asbestos fiber of the same morphology and chemical composition.[27]

EPA Region 9 focused on obtaining an accurate count of PCME structures, consistent with our risk assessment protocols and those of Cal/EPA and other health agencies. The counting rules which EPA set for the laboratory were designed to stop counting when a statistically-significant number of PCME fibers were detected. By concentrating on PCME structures, other fiber size classifications may not have been counted to statistical significance. This may have resulted in under counts of other fiber sizes (e.g. the "Berman Crump" protocol fibers referred to in the R. J. Lee Report). **EPA Region 9's study counted PCME structures so that the data could be directly compared to human health epidemiological studies.** These epidemiological studies form the basis for risk assessment models currently used by EPA, Cal/EPA and other federal agencies and international organizations.

R. J. Lee Report Peer Reviews

The R. J. Lee Report was reviewed by three individuals, although research of one of the individuals was extensively quoted in the report and therefore the independence of the reviewer is debatable. The three reviewers generally agree with the conclusions of the R. J. Lee Report regarding aluminum content, fiber chemistry, cleavage fragments, and extinction angles.

Both the R. J. Lee Report and one of the reviewers support use of the original "Berman-

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[26]USEPA (U.S. Environmental Protection Agency) (2003). Report on the Peer Consultation Workshop to Discuss a Proposed Protocol to Assess Asbestos-Related Risk, Final Report. Office of Solid Waste and Emergency Response, Washington D.C. Page 5-5.

[27]Ibid, page 5-1.

Crump" protocol and calculate a "Berman-Crump" fiber air concentration of 0.0002 fibers/cubic centimeter, using the EPA fibers which they assert meet the "Berman-Crump" definition. The peer reviewer then compares that concentration with an ambient concentration of 0.0008 fibers/milliliter measured in New York City, and states that the "Berman-Crump" value in El Dorado Hills is extremely low. This comparison is flawed for at least two reasons. Significantly, the New York City numbers are based on fibers counted against a totally different size classification (essentially comparing apples to oranges), but **the reviewer also fails to recognize that a concentration of 0.0002 f/cc translates in the protocol to an increased cancer risk of 1 in 1,000 exposed individuals.** This number is disturbingly high and is outside the acceptable cancer risk ranges of EPA, Cal/EPA, and most other state and federal health agencies.

Conclusions

EPA Region 9 has carefully reviewed the R. J. Lee Report and believes that it makes largely unsupported and incorrect conclusions about the EPA Region 9 El Dorado Hills Naturally Occurring Asbestos Exposure Assessment. EPA Region 9 has asked the United States Geological Survey (USGS) to conduct an independent study of the El Dorado County area to address several mineralogical questions raised by the R. J. Lee Report. The USGS study will use sophisticated analytical techniques (such as electron probe micro analysis) to more completely characterize the naturally occurring asbestos in terms of mineral identification and particle morphology.

All of the EPA Region 9 work in El Dorado Hills was, and continues to be, consistent with the EPA's standard operating and quality control procedures for asbestos work throughout the country.

Exhibit 61

Review of Material Analytical Services (MAS) Reports on Johnson & Johnson Talc Products Identifying "Chrysotile" by Polarized Light Microscopy

by

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College Park, Maryland
May 3, 2024

Introduction

I graduated *cum laude* from Wellesley College with a degree in Geology in 1966. I received my Ph.D. from Columbia University in 1972 with a major in economic geology, and minors in mineralogy, petrology and mining engineering. I was appointed Assistant Professor by the Department of Agronomy at the University of Maryland in 1972, but one year later the appointment was transferred to the newly formed Department of Geology. I retired as Professor of Geology and Distinguished Scholar Teacher in 2014, but continue to hold an appointment as Professor Emerita. In addition to my academic appointments, between 2000 and 2014, I held a variety of senior level administrative appointments, including Assistant President and Chief of Staff, Vice President for Administrative Affairs, and Senior Vice President and Provost. Between 1979 and 2024, I published, among others, 47 articles on talc, amphibole and/or asbestos in highly regarded peer-reviewed publications. My work on mineral fiber and human health has been recently recognized by the United States Congress.

I taught polarized light microscopy and optical mineralogy at the University of Maryland, College Park for almost 30 years. My Ph.D. dissertation at Columbia University was in polarized light microscopy. I am thoroughly familiar with the methods of dispersion staining. My curriculum vitae is attached at the end of this report as Appendix 4.

I am being compensated at a rate of $450 per hour for my expert work in this litigation. I have not testified at trial or deposition during the past four years.

I have reviewed numerous reports produced by MAS since 2020 involving the identification of "chrysotile" in Johnson & Johnson's talcum powder products by polarized light microscopy involving dispersion staining techniques. A list of the MAS reports on this subject that I have reviewed is included as Appendix 5.

In my opinion, there is no scientifically-based evidence presented in these reports that supports the presence of chrysotile in any of the samples examined by MAS. Instead, the evidence presented is consistent with the conclusion that the particles MAS identified as chrysotile are actually composed of the mineral talc.[1]

[1] One particle identified by PLM is neither talc nor chrysotile, but there is insufficient data available to specifically identify the particle beyond concluding that it is not asbestos.

In this report, I will discuss the raw data from the MAS reports to demonstrate my conclusion. I have selected examples that are typical, not unusual, to illustrate the points and I provide additional examples in the appendices. The types of raw data from particles identified as chrysotile from these reports that I specifically utilized for my assessment include:

1. Dispersion staining color parallel and perpendicular to the elongation direction of the particles,
2. Determination of the sign of elongation,
3. The relationships between particle size, retardation, and birefringence,
4. The extinction and interference patterns of the particles, and
5. The relief of particles in oil mounts.

I will also discuss the methodological issues of the MAS approaches, including impact of neglecting to correct for temperature variations, MAS deviations from standard methods of analysis, and other issues that impact the reliability of the MAS reports.

A. Polarized light microscopy: General considerations.

The polarized light microscope is highly specialized to enable examination of the optical properties of crystalline substances.

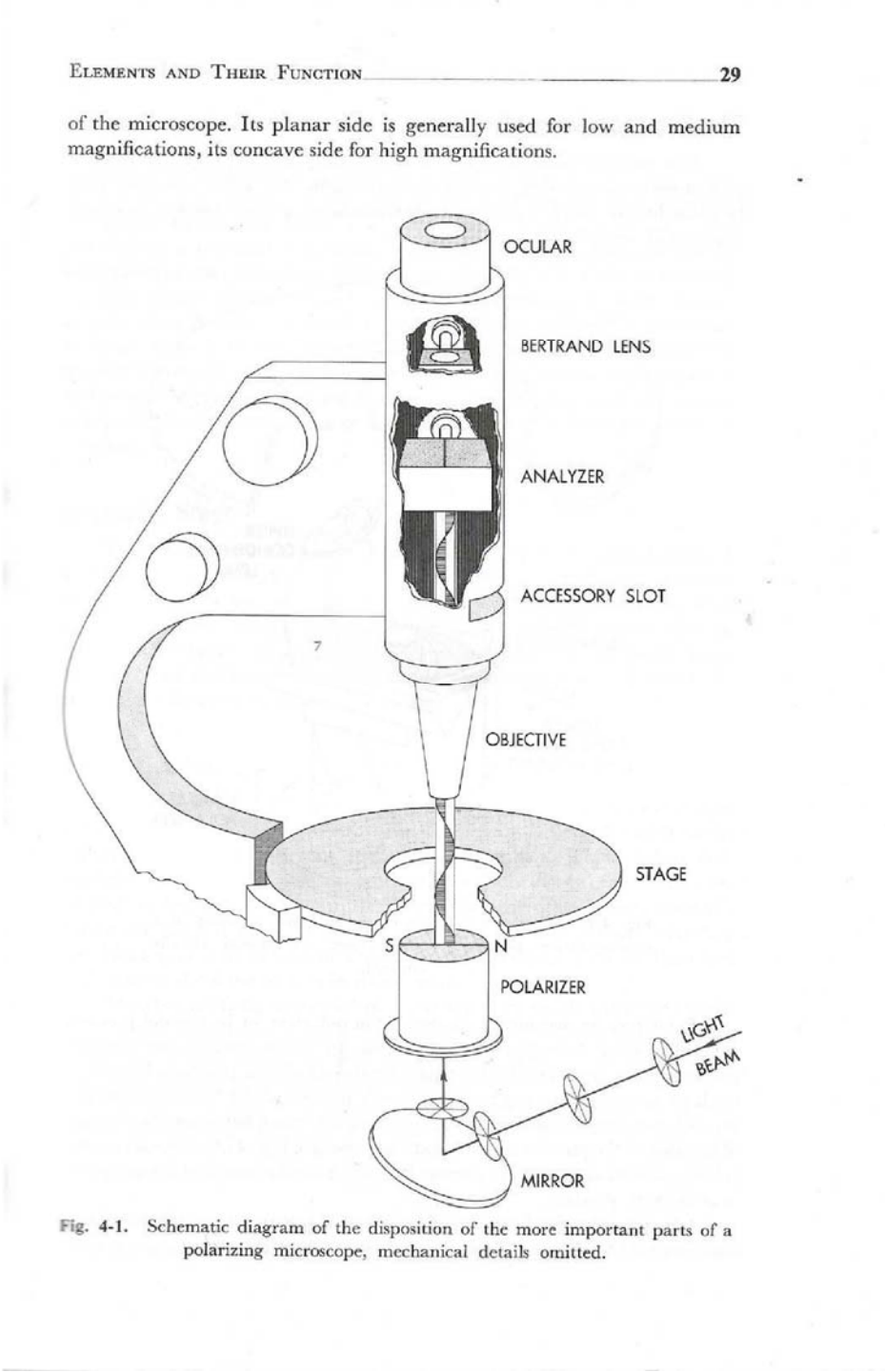
Figure 1 shows an overview of the polarized light microscope (Bloss, 1960[2]). The microscope differs from biological microscopes by the fact that there is a polarizer introduced in the system below the stage so that when the light enters the object, it is constrained to vibrate in only one direction, identified as North-South (N and S) in the figure. The object can then be rotated to look at light-object interactions in different crystallographic directions within the mineral. Because minerals are crystalline, the atomic structures of most are not the same in all directions, and their optical properties are also not the same in all directions; this is always the case for the two minerals with which we are concerned: talc and chrysotile. Imagine a pencil-shaped object on the microscope stage. By turning this object, you can observe how it affects light when its long side aligns with or crosses the light's vibration direction.

Another polarizer, named the analyzer, is placed in the optical path and is oriented at a 90-degree angle to the lower polarizer. There is also a slot for adding a "compensator," with MAS using one called Red I to determine the sign of elongation. Although not depicted in **Figure 1**, if a tungsten light source is utilized, a blue filter should be added above it. This filter reduces the red intensity from the tungsten, aligning the light spectrum more closely with that of the north sky, which appears as uniform, "white" light across the visible spectrum.

If a pencil-shaped mineral is positioned at an angle to the polarizer and analyzer, when light enters the mineral particle, a component of the light will travel through the mineral parallel to elongation and perpendicular, and when these two rays emerge, they will interfere. If the second polarizer is in the optical path, we will see interference colors like the colors one sees from an oil slick on water. If the angle is 45 degrees, we designate this the 45-degree position.

[2] Bloss, F. Donald, An introduction to the Methods of Optical Crystallography. Holt, Rinehart and Winston, New York, 1960. A list of references is included as Appendix 6.

Figure 1. Elements of the Polarizing Microscope (derived from Bloss, 1960[3])



[3] Bloss, F. Donald, An introduction to the Methods of Optical Crystallography. Holt, Rinehart and Winston, New York, 1960, at 25.

B. What properties can be measured by Polarized Light Microscopy?

The incorrect identification of talc particles as chrysotile would have been evident if all optical properties of the suspect minerals had been evaluated.

Polarized light microscopy has been used for more than 200 years by mineralogists to identify minerals. Most minerals were originally named and differentiated from other minerals based on their optical properties. There are many properties that can be determined **independently** by polarized light microscopy, and together they provide under most circumstances sufficient information to differentiate one silicate mineral from another. These properties include:

1. Optical group (uniaxial, isotropic or biaxial)
2. Indices of refraction
3. Birefringence
4. Size and sign of the optic axial angle in biaxial minerals
5. Dispersion of the optic axes
6. Orientation of principle indices of refraction and cleavage
7. Color
8. Relief (relative to matrix)
9. Form
10. Sign of elongation (if elongated)
11. Extinction angle (to elongation or cleavage)

All of these properties could have been determined by MAS in their identification of an unknown as chrysotile. In my practice, I use all of the parameters 1-11 to identify minerals by polarized light microscopy.

To the contrary, MAS did not do so. In the MAS reports, there is no mention of the **optical group**, the **optic axial angle**, **the dispersion of the optic axes**, **the orientation of the principal indices of refraction and cleavage**, or the **mineral color**. Furthermore, as I will explain, although the information on measuring the **birefringence** independent of the measurement of indices of refraction is possible, MAS did not make this measurement. In simple terms, birefringence is the difference in the indices of refraction of parallel and perpendicular to elongation Instead, MAS derived a birefringence from the indices of refraction it reports. Had MAS measured birefringence independently, it would have been clear that the **indices of refraction it reports are incorrect**. Although MAS reports that some of the particles are fiber bundles, this **form** is not consistent with the evidence provided. MAS did determine the **sign of elongation** as it is the same for both chrysotile and talc, and for that reason, I will not discuss that property further. Many minerals have a positive sign of elongation. Talc usually has a slight **angle of extinction (about 10 degrees)** but there is no evidence to indicate that MAS ever measured this angle precisely.

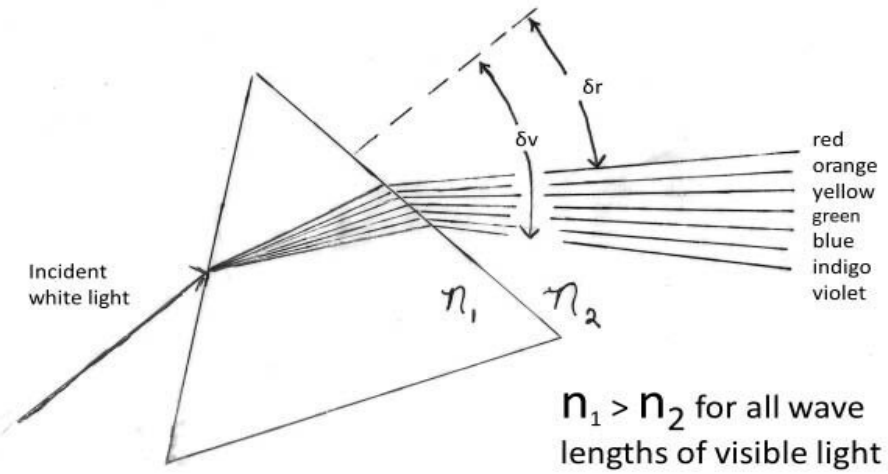
Although MAS did not utilize the full capabilities of polarized light microscopy in the incorrect identification of talc particles as chrysotile, the MAS reports provide enough raw data to differentiate chrysotile from talc .and other materials in talcum powders.

C. Dispersion staining, dispersion of the index of refraction and λ_0.

MAS incorrectly interpreted the dispersion staining colors to derive an index of refraction. The correct interpretation of the dispersion staining colors would result in indices of refraction that are inconsistent with chrysotile but consistent with talc.

The MAS conclusion that identifies a particle as chrysotile is mainly based on the particle's indices of refraction, determined by dispersion staining, and a birefringence calculated from the indices of refraction. MAS's raw data come from central stop dispersion staining images, showing colors parallel and perpendicular to the particle's elongation. MAS's mistakes stem from two issues: first, using colors from dispersion staining with only one immersion oil (usually 1.550 Series E, sometimes 1.560 Series E) instead of the recommended two or three[4]; and second, making unfounded extrapolations to a reference index of refraction. To clarify these errors, I will briefly explain how dispersion staining functions.

Figure 2. What is dispersion?



In **Figure 2**, light enters a glass prism from the left at an angle to the surface. If the indices of refraction of the solid (n_1) are different from the surrounding medium (n_2), the light rays will be bent. Because white light is composed of a range of wavelengths (from about 400-700nm) light of different wavelengths travels through this solid at different speeds, and they are bent. Because of this, they travel along different paths. When they emerge on the right side, the colors (wavelengths) of visible light are separated. This is called dispersion.

[4] Bloss, F. Donald, Optical Crystallography. MSA Monograph Series 5. Mineralogical Society of America, 1999, at p.55.

Figure 3. Illumination by monochromatic light (from Bloss 1999[5])

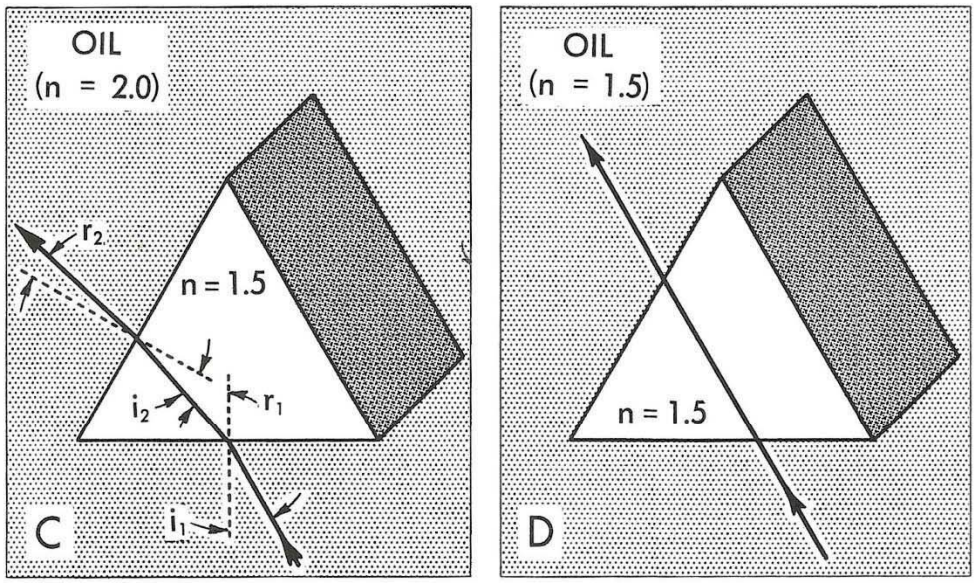


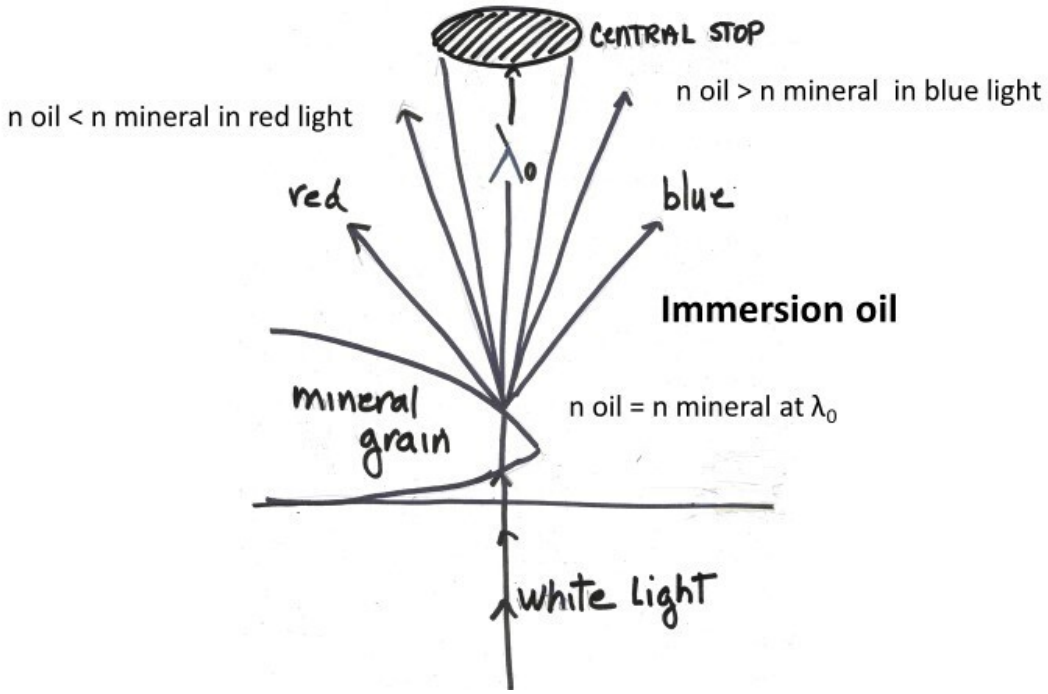
Fig. 2-3. Successive refraction of a light ray by two parallel interfaces (A) and by two nonparallel interfaces (B), (C), or (D). The front half of each glass solid has been removed to expose the plane of incidence. In (C) the glass prism is immersed in an oil of larger index than the glass; in (D) the glass and oil have identical indices.

In **Figure 3**, the prism is illuminated by light with only a single wavelength, unlike white light, which contains multiple wavelengths. On the left, how much the light bends depends on the angle it hits the prism, labeled i_1, and the difference in how fast light travels through the prism versus the air or oil around it. On the right, because the light speed inside the prism and in the surrounding medium is the same at this wavelength, the light does not bend.

These simple concepts can be used to understand how dispersion staining works. In **Figure 4**, white light illuminates a mineral grain that is sitting on the microscope stage. In this example, the mineral and the immersion oil in which it sits have the same index of refraction at a wavelength labeled λ_0. For red light, the index of refraction of the oil is less than the index of refraction of the mineral and in blue light the opposite is the case. For this reason, the ray paths for red light and for blue light are bent and diverge.

[5] Bloss, F. Donald, Optical Crystallography. MSA Monograph Series 5. Mineralogical Society of America, 1999, Figure 2.3 p.11.

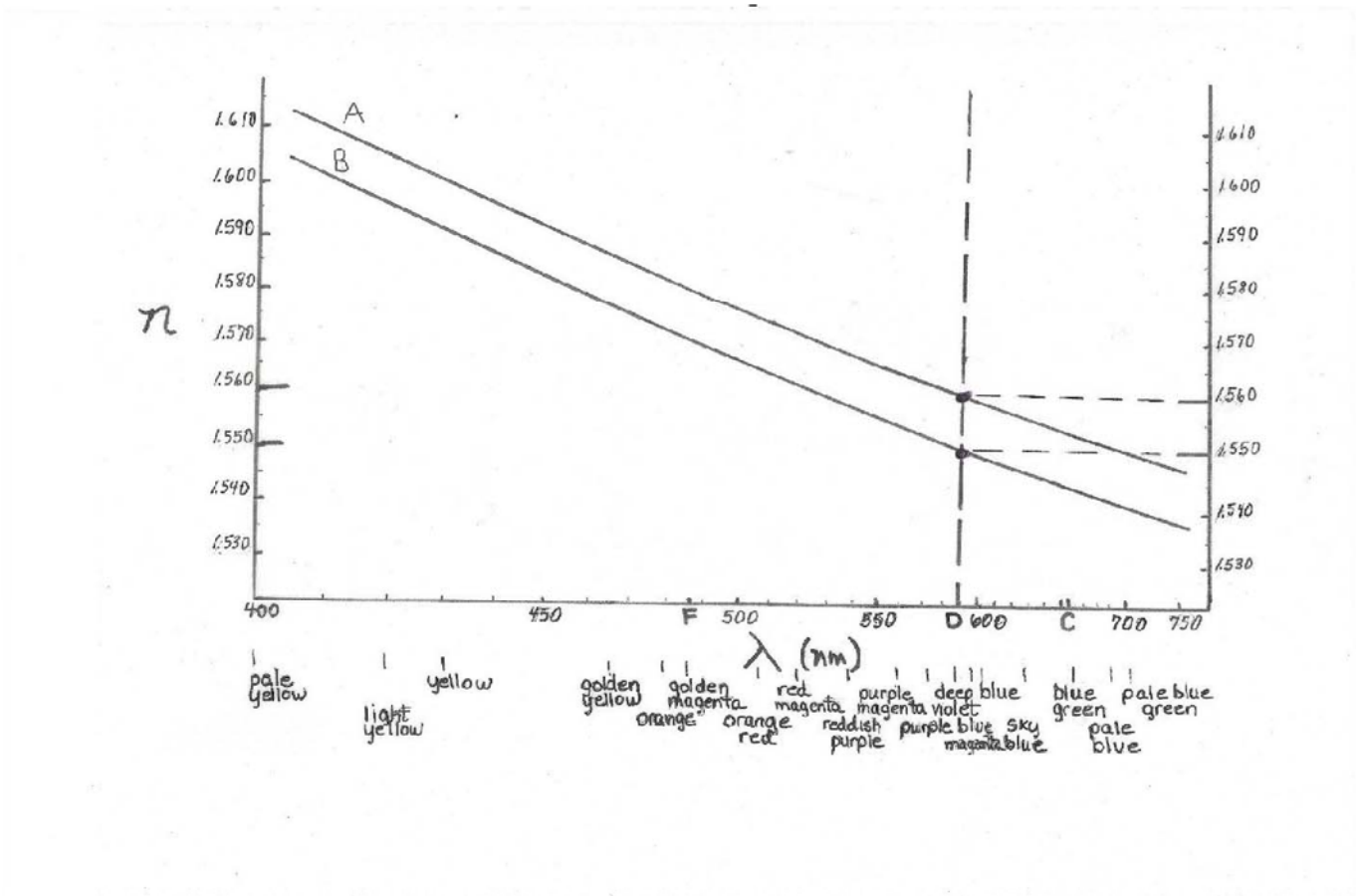
Figure 4. Dispersion staining and λ_0.



In central stop dispersion staining, an opaque disc is placed on the back of the microscope objective in the center, blocking all light that cannot be bent around it. For minerals, the center of the grains normally is black, because the angle of incidence is near zero (90-degree angle) and when that is the case, even when the indices of refraction of grain and mineral are different, there is no bending. For the same reason, in the field of view without particles, the light is also blocked by the central stop and appears black. However, on the grain edges, color appears if some of the visible light is removed by the stop. The wavelength removed is that for which the index of refraction of the mineral and oil are the same, because at that wave length light does not bend. The matching wavelength is referred to as λ_0. In the example shown in **Figure 4**, λ_0 is at a wavelength near the center of the spectrum of white light, so the color along the edges would be seen as purple as the red and blue bend around the central stop and then are combined by the objective when the image is formed. This is the origin of the "stain" in dispersion staining. It is not a stain like coffee on a white blouse, which is a pigment stain. It is a color that depends on the wavelength of λ_0, and λ_0 is controlled by the index of refraction of the mineral and the oil in which it is immersed. For a dispersion staining color to be visible, the index of refraction of the mineral and the oil must be the same at some wavelength within visible light.

When observing this phenomenon without the central stop in place, one can see a yellowish line on the grain boundary and just outside of it, a bluish line. These are called Becke lines.

Figure 5. Dispersion of the Series E oils and D, the wave length of reference. Data from Cargille[6], the manufacturer of the oils.

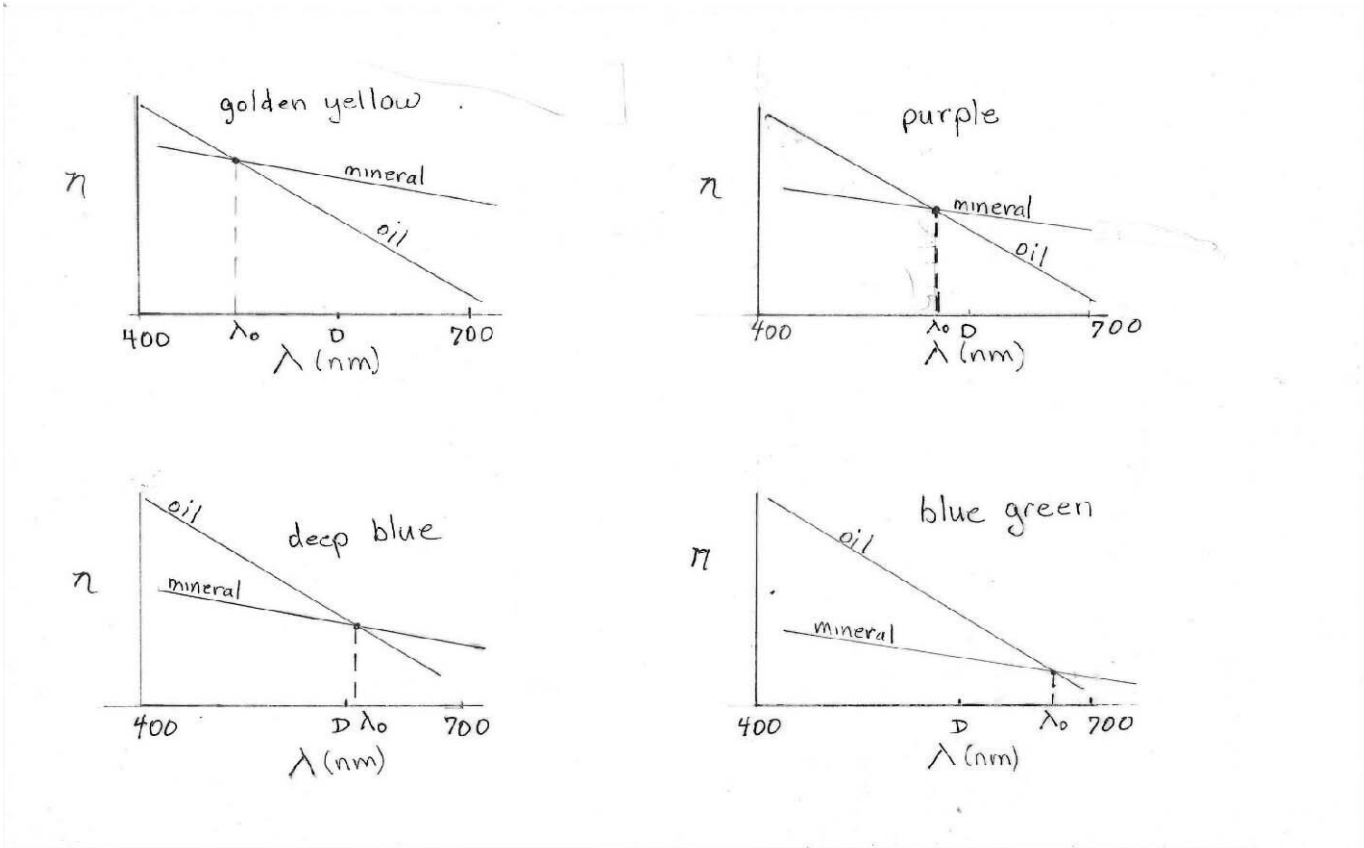


In **Figure 5**, the index of refraction (n) is plotted on the vertical Y-axis, while wavelength is on the horizontal X-axis. This figure also gives along the X-axis the dispersion staining colors observed at specific wavelengths for λ_0. The two oils, A and B, display a broad variation in their indices of refraction across different wavelengths, known as their dispersion. This dispersion is indicated on the Cargille oil bottles as nF-nC, representing the difference between the indices of refraction at two other reference wavelengths, F and C, which are highlighted in the figure.

For all minerals and oils, the "index of refraction" on the label or in reference texts is the index at a particular wavelength of reference, referred to as the D line. (There are a number of wavelengths missing from the sun's spectrum, labeled, A, B, C… and this is the D wavelength.) D corresponds to a wavelength of 589 nanometers. When we look up optical data in a table of mineral data, what are given are the values at the D wavelength. When MAS says that the index of refraction of a mineral particle is 1.562, that refers to the index at the D wavelength. The two oils used by MAS are labeled 1.550 and 1.560 because the index of refraction of those oils have these values at the D wavelength.

[6] Cargille, Refractive Index Liquids, *available at* https://www.cargille.com/refractive-index-liquids/.

Figure 6a. Dispersion of the indices of refraction of oils and minerals and the central stop dispersion staining colors



In **Figure 6a**, I have shown the variation of wavelength for a mineral and four different oils such that at some wavelength in the visible the two are equivalent. That wavelength is labeled λ_0. You will notice that the dispersion of the oil (change in index of refraction with wavelength) is always greater than that of the mineral. This is a general principle and the oils are formulated to ensure that this is the case. If λ_0 occurs in the blue end of the spectrum so that some of the blue light is removed by the central stop on the back of the objective, then the "stain" will be yellow. If the matches are near the D line, the colors will be purple when the match is just below the D line and deep blue when it is close or just above D. Sometime, when the particles are small, the stain colors will be hard to see if λ_0 is close to the D wavelength. When the match is in the red end of the spectrum, the staining colors will be blue green.

In this figure, I have shown a mineral with a fairly strong dispersion, i.e., the slope of the line representing the mineral's index of refraction is less than the oil but still significant. Minerals vary a great deal in how strong their dispersion will be in visible light, i.e., how much the line relating index of refraction to wavelength will slope. This variation is an important property in the interpretation of dispersion staining colors with respect to the value of the index of refraction of the mineral at the reference D w. But one thing that does not vary is the relationship between the dispersion staining color and λ_0. They are independent of the absolute values of the indices of refraction of either oil or mineral.

Figure 6b. λ_0 Central stop dispersion staining colors.[6]

λ_0	Central Stop Dispersion Staining colors
700	pale blue green (S)
680	pale blue (M)
660	bright greenish blue(B) blue-green(M) lt blue green(S)
625	sky blue(B) blue(M) blue-green(S)
600	blue(M)
595	deep blue(S) blue-magenta(M)
589 **D**	deep violet (B)
575	purple(B)
560	purple(S) magenta(M)
540	reddish purple(B)
520	red purple(S) red-magenta (M)
505	orange-red(B)
485	orange(S); golden magenta (M)
480	orange(B)
465	bright gold(B)
455	golden yellow(M)
430	yellow(M)
420	light yellow(M)
400	pale yellow(S)

To determine λ_0, one must identify the dispersion staining color and compare that color to the descriptions given in **Figure 6b**, or one can use a monochromator in the optical system and measure it precisely. In some of the MAS optical data sheets, specific values for λ_0 parallel and perpendicular to elongation are provided; in others, one can only estimate the value of λ_0 from the color in the photograph.

Below, in **Figure 7** I have copied three photographs from three different MAS reports. The first shows a particle 49.6 µm in length that is identified as chrysotile. The rest of the particles in the photograph are not identified, nor are they claimed to be chrysotile. They are talc. There are several things to note in **Figure 7a**. First, the dispersion staining colors of all the particles are very similar. I would note that they are a bit more orange than I would expect for 1.550 oil, which is either due to the fact that the voltage of the tungsten light source was too low, or a blue filter, which must be present in the optical system to properly interpret the dispersion staining colors, is missing. What is clear, however, is that all particles that have the same dispersion staining colors have the same λ_0 and the same index of refraction at λ_0. Based on the chart of colors, the yellow colors indicate that λ_0 is in the blue end (about 440nm) of the spectrum. Note also that the other prominent color in some grains is a bright sky blue. These grains are oriented so that for them, λ_0 is in the red end of the spectrum (about 640 nm). There is some uncertainty in the estimates due to color interpretation (**Figure 6**) and to experimental conditions discussed later, e.g., temperature.

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[6] M is from The Asbestos Particle Atlas written by Walter McCrone, published by Ann Arbor Science, Ann Arbor Michigan 1980. Table 4, P. 25.
S is from Shu-Chun, Su., A rapid and accurate procedure for the determination of refractive indices of regulated asbestos minerals, American Mineralogist 88:179-182, 2003, Table 2 p.1981.
B is from Bloss, F. Donald, Optical Crystallography. MSA Monograph Series 5. Mineralogical Society of America, 1999, Table 5.1 p.55.

Figure 7a.

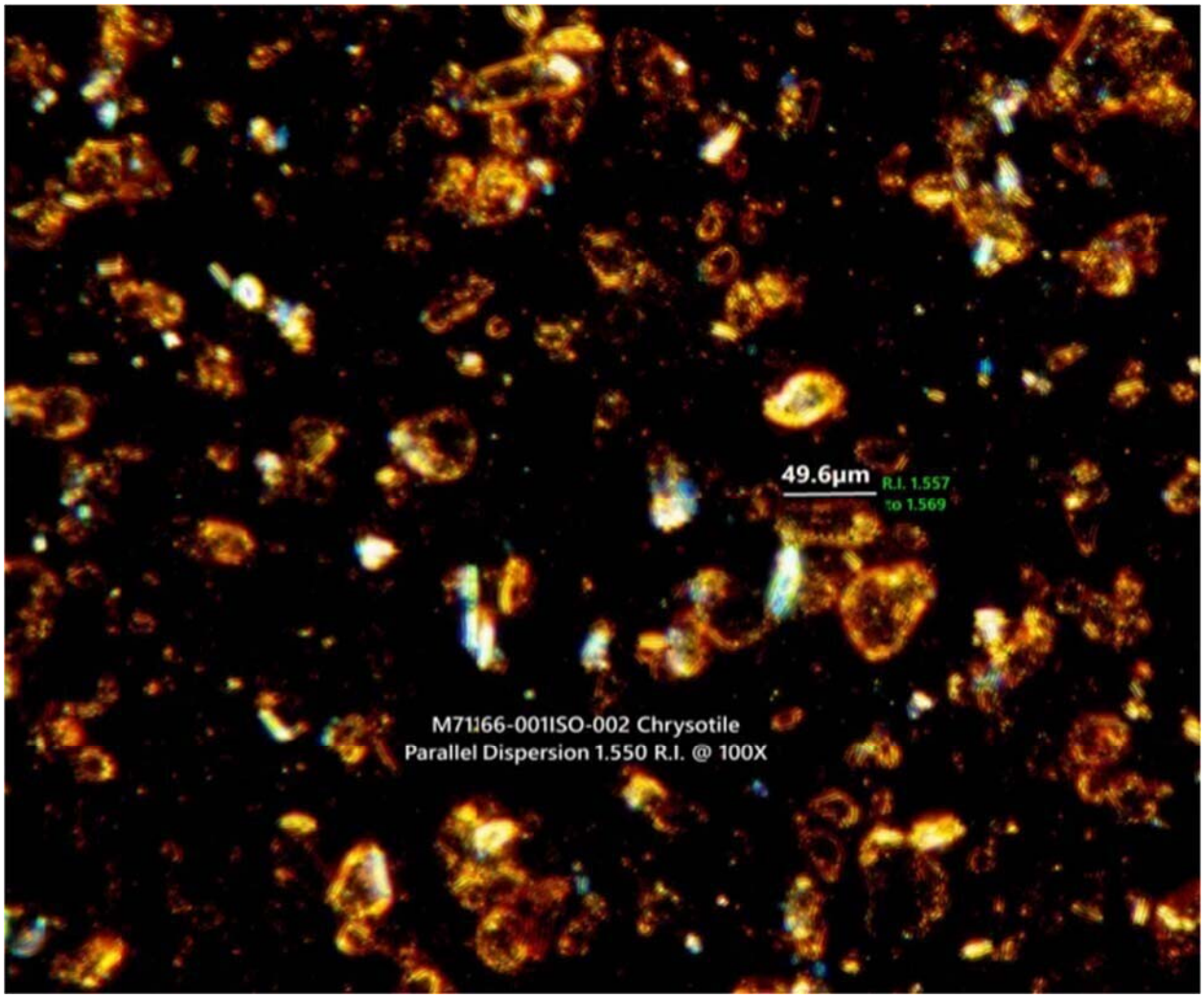

49.6µm
R.I. 1.557
to 1.569
M71166-001ISO-002 Chrysotile
Parallel Dispersion 1.550 R.I. @ 100X

Figure 7b.

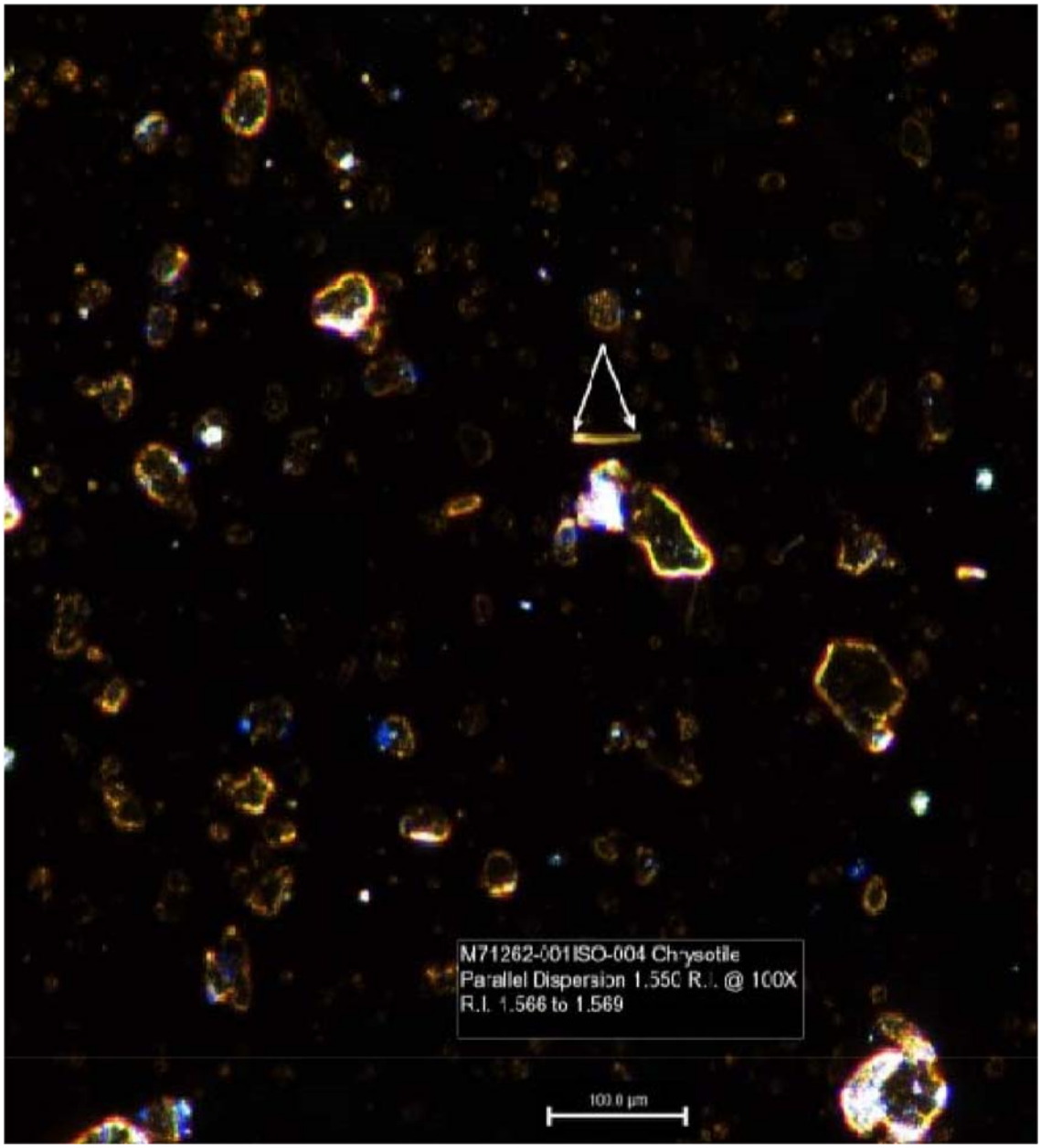


Figure 7b was taken of a different sample at a later time by MAS. The colors are now a much clearer yellow, but the same conclusions can be drawn. The particle labeled as chrysotile stains a bright yellow, and so do many of the talc particles, just as was the case in **Figure 7a**. The other color in some of the talc particles is also blue.

Figure 7c.

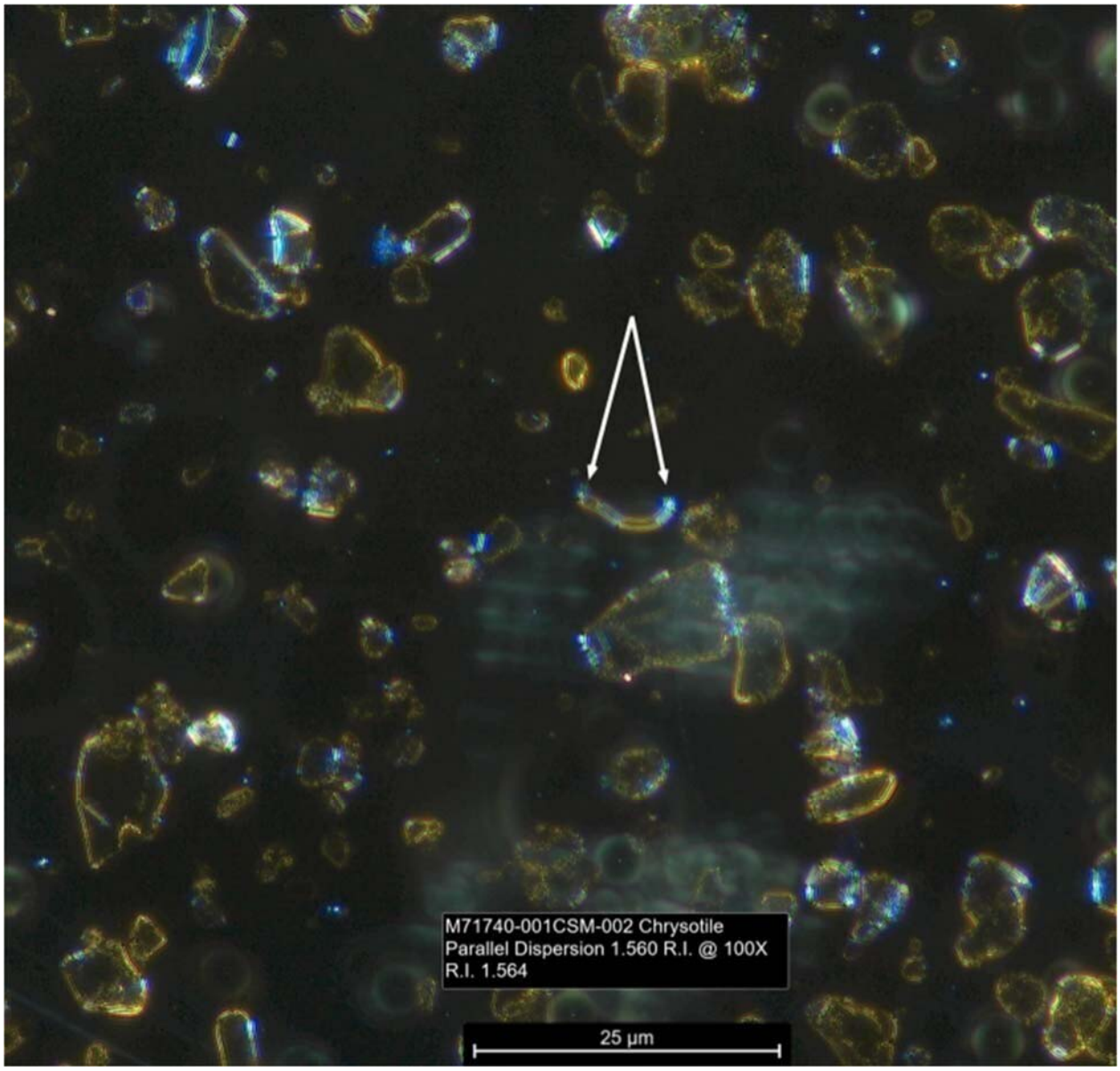


Figure 7c was taken in a different oil, 1.560 Series E. The yellow colors of the talc particles are slightly more golden than in Figure 7b, and the blues are slightly bluer green. We would expect slight shifts in λ_0 to the right (higher wavelength) as the indices of refraction of the oil increase from 1.550 to 1.560. In **Figure 7c**, the particle identified as chrysotile is oriented such that the index of refraction is associated with the ray that vibrates perpendicular to elongation, which has a lower index of refraction than were it oriented parallel to elongation, as the particles were in Figures 7a and b. Again, as was the case in Figures 7a and b, the so-called chrysotile displays the same dispersion staining colors as many of the talc particles, and therefore they have the same index of refraction in 1.560 Series E oil and the same λ_0.

Our first conclusion from **Figure 7** is that talc and "chrysotile" are not distinguished from each other by MAS by dispersion staining colors. In my opinion, this is because the particles identified as chrysotile are not chrysotile at all. The particles should be objectively identified as talc, and not chrysotile, because they are identical to other talc particles in the samples, and there is no scientific data that would suggest otherwise. Other examples of the dispersion staining colors of talc and the particles MAS indicates are chrysotile are provided in Appendix 1.

D. How do derive an index of refraction at the D wavelength from a dispersion staining color?

A major error MAS makes is the relationship between the dispersion staining colors (λ_0) and the index of refraction at the D wavelength of reference.

For reference, in **Figure 7a** MAS reports the index of refraction parallel to elongation at the D wavelength for the identified particle as 1.557-1.569; for the particle in **Figure 7b**, MAS reports 1.566-1.569 parallel to elongation, and for the particle in **Figure 7c**, perpendicular to elongation, MAS reports 1.564 as the value at the D wavelength. In my opinion, the colors in **Figures 7a** and **7b** (also shown in Appendix 1) are indicative of a mineral with an index of refraction closer to 1.586 parallel to elongation. Because the colors in **Figure 7c** are blue green, the mineral must have a lower index of refraction perpendicular to elongation than the oil, which in this case is 1.560. In other words, the index of refraction cannot be 1.564 and stain blue in 1.560 oil as MAS asserts.

So, we might ask, how do I know that a yellow color means that the index of refraction at the D line is closer to 1.586 than it is to 1.566 and why can't a mineral that stains blue in 1.560 have a higher index of refraction than 1.560?

To explain that, I will analyze carefully the dispersion staining color shown in **Figure 8**.[7] **Figure 8** shows a particle that is 34.1µm in length immersed in oil nD = 1.550 Series E and identified as chrysotile by MAS. In **Figure 8a**, the particle is oriented so that the polarizer constrains the light to vibrate parallel to elongation, and in **Figure 8b**, the particle has been rotated 90 degrees so the light vibrates perpendicular to elongation. Parallel to elongation, the dispersion staining color is yellow and perpendicular the color is blue green. Note also, as was pointed out in **Figure 7**, the talc particles stain the same colors, indicating the same index of refraction at λ_0.

[7] Although only one photomicrograph is discussed in this section, most of the particles identified as chrysotile show dispersion staining colors that are similar. Other examples can be found in Appendix 1.

Figure 8a.

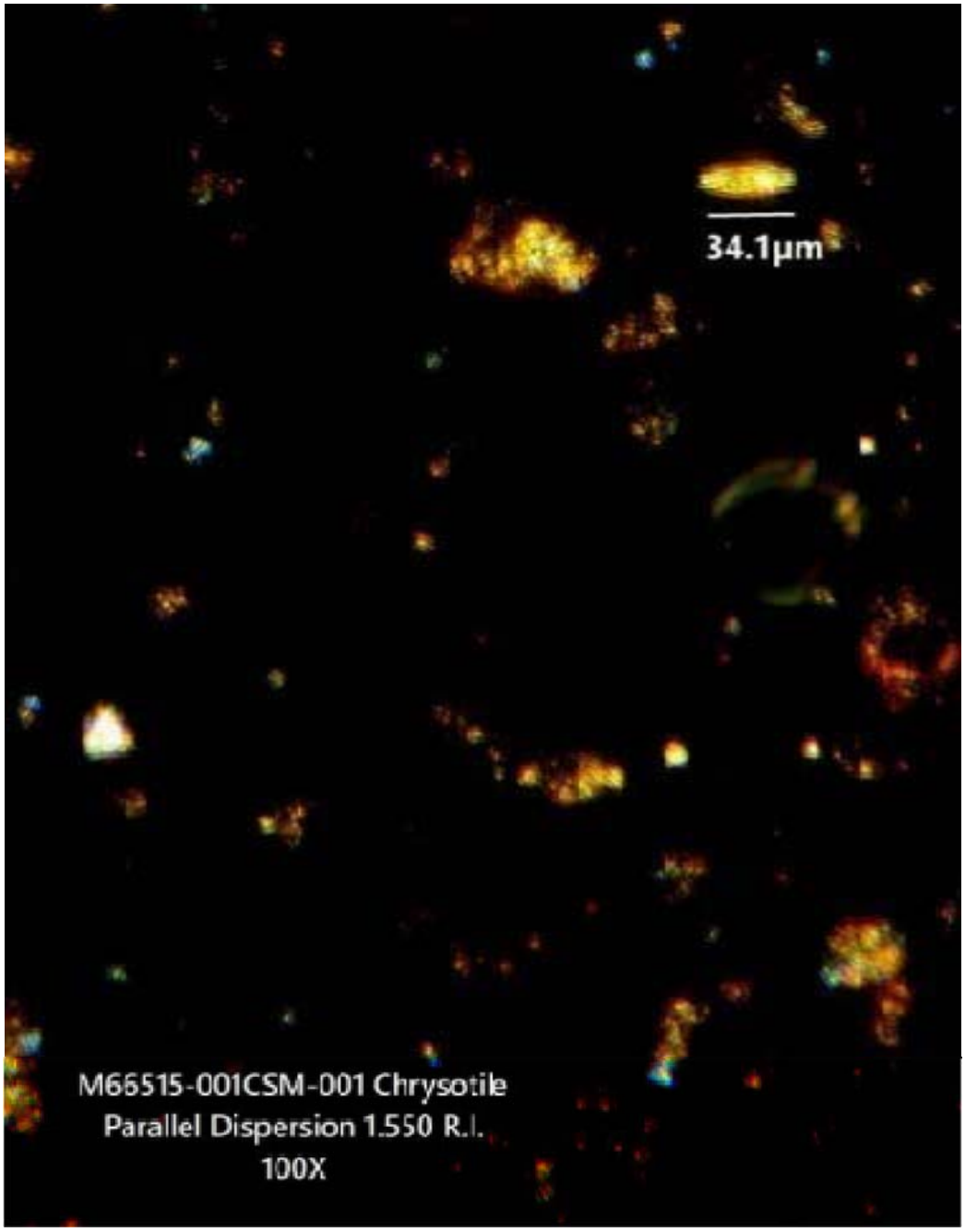
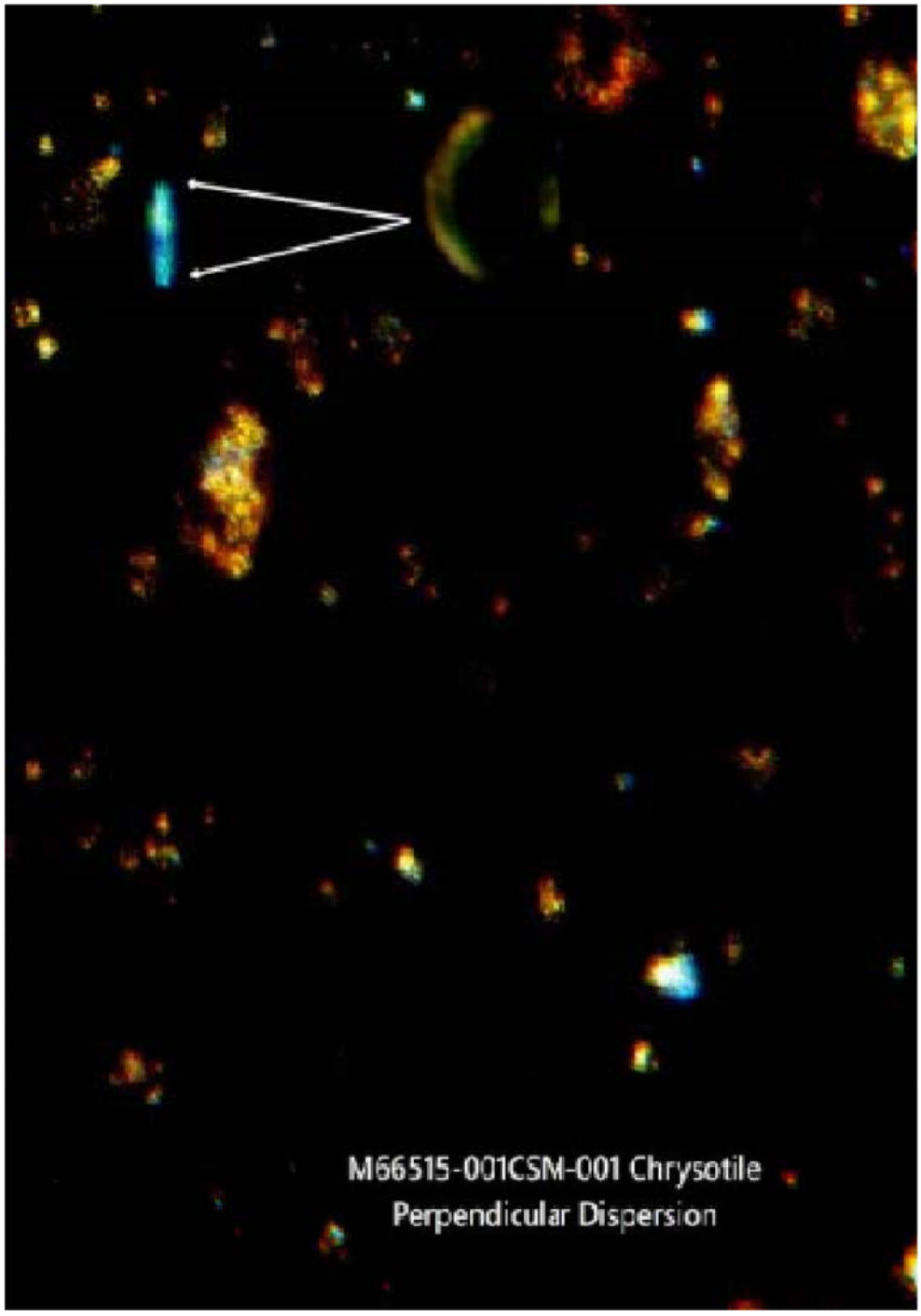
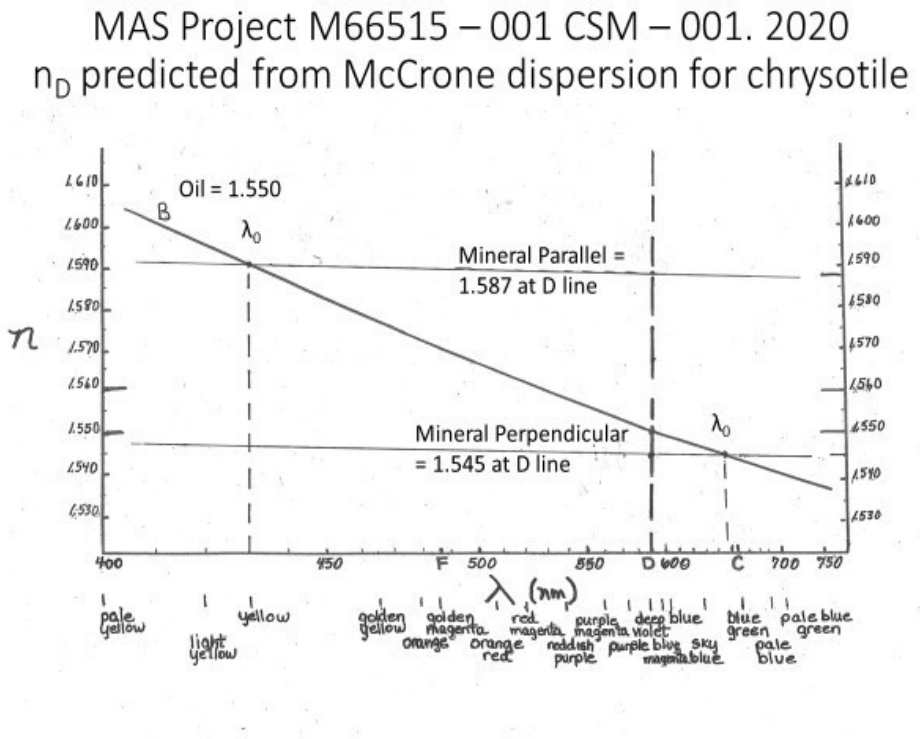

34.1µm
M66515-001CSM-001 Chrysotile
Parallel Dispersion 1.550 R.I.
100X

Figure 8b.



In **Figure 9**, I have plotted the dispersion for 1.550 Series E oil and the observed λ_0 for a particle shown in **Figure 8**, both parallel and perpendicular to its elongation. For the particle in **Figure 8**, λ_0 is around 430 nm parallel and about 645 nm perpendicular to elongation. I drew a line from λ_0 to the D line in both orientations, slightly off horizontal. This approach is based on dispersion data for chrysotile from Walter McCrone, who popularized dispersion staining for identifying commercially mined asbestos. McCrone's data show that the dispersion of chrysotile's refraction index is 0.003 parallel and 0.001 perpendicular to elongation.[8] Assuming this dispersion, the indices of refraction estimated for this particle at the D line are 1.587 parallel to elongation and 1.545 perpendicular. These indices of refraction would not correspond to indices of refraction required for chrysotile identification. MAS incorrectly reported different indices for this particle.

Figure 9. Data on dispersion of chrysotile from McCrone[7]

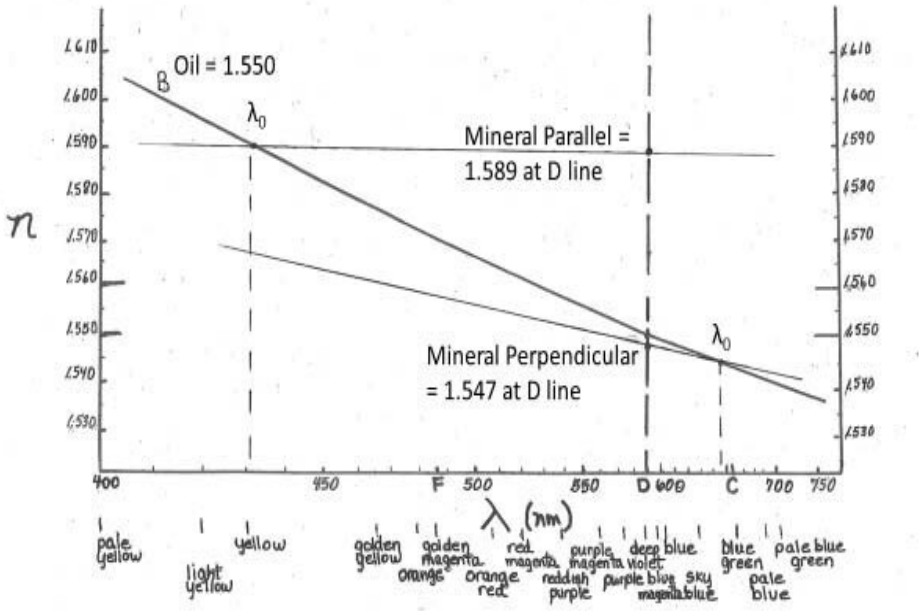


[8] McCrone, Walter. Undated Determinative Tables and Charts supplied with the McCrone Dispersion Staining Objectives. Published by Walter C McCrone Associates, Chicago Illinois as the Particle Analyst's Handbook.

Could this particle then be talc? McCrone also provides the dispersion of talc parallel and perpendicular to elongation and those data are plotted in **Figure 10**.

Figure 10.

MAS Project M66515 – 001 CSM – 001. 2020. n_D predicted from McCrone dispersion for talc. λ_0 at 430 and 645 nm.



According to McCrone, the dispersion of the index of refraction of talc parallel to elongation is very small with nF-nC = 0.001, so this curve is almost flat. On the other hand, perpendicular to elongation the dispersion is quite high. By using the dispersion of talc, the indices of refraction of this grain can be estimated as 1.589 and 1.547.

MAS reports the indices of refraction of this grain as 1.557 to 1.569. **There is no explanation of how MAS uses an observation of a single dispersion staining color in a single oil to derive the value of the index of refraction at the D line**. One must know either the dispersion of the mineral to begin with, hence it is not an unknown, or follow the guidance of the textbooks on dispersion staining for mineral identification, which requires observations of dispersion staining colors in two or more oils.

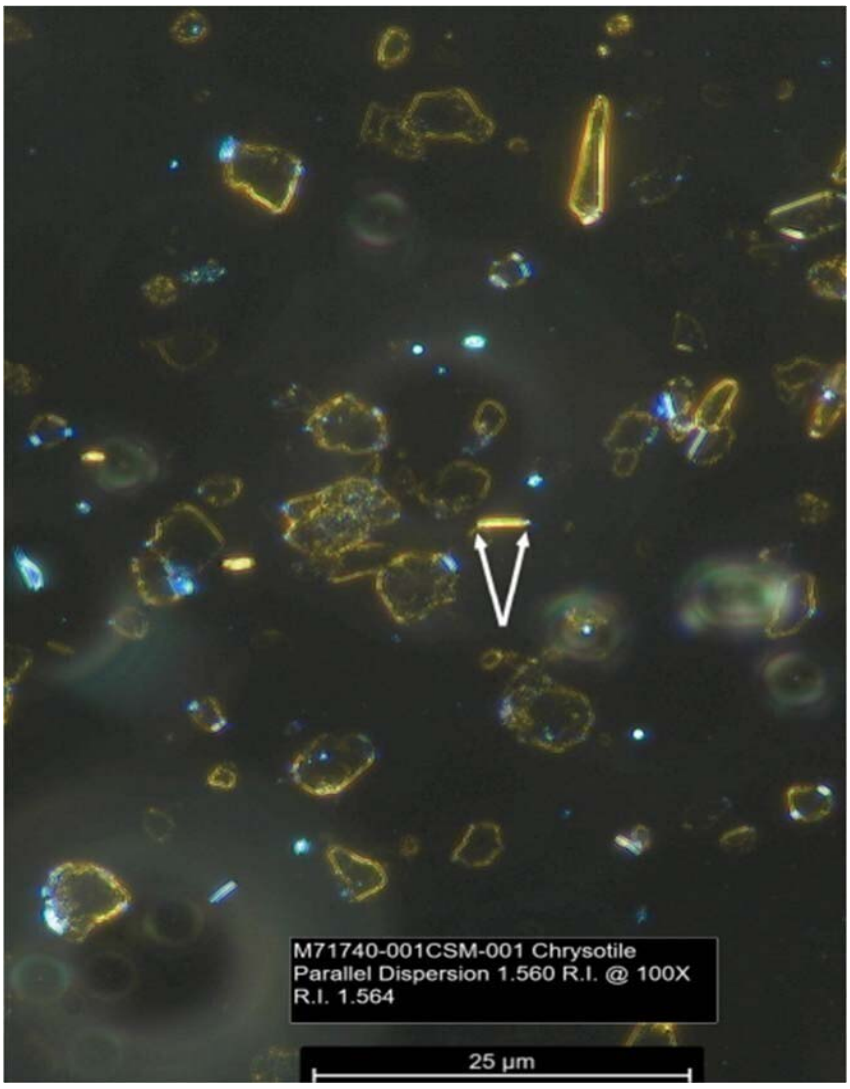
E. Determining n_D from observations in two oils.

Had MAS used more than one immersion oil, λ_0 parallel and perpendicular could have been used to determine n_D without knowing the dispersion. Not doing so is inconsistent with standard practice in the identification of an unknown.

We can use the dispersion staining colors MAS reports parallel to elongation in Series E oils 1.550 and 1.560 to test the hypothesis that the dispersion of the particles identified as chrysotile is very small, without knowing the mineral or assuming its dispersion.

In **Figure 11** below, the dispersion staining colors of the MAS identified "chrysotile" in oil 1.560 Series E are shown.

Figure 11. Dispersion colors parallel to elongation

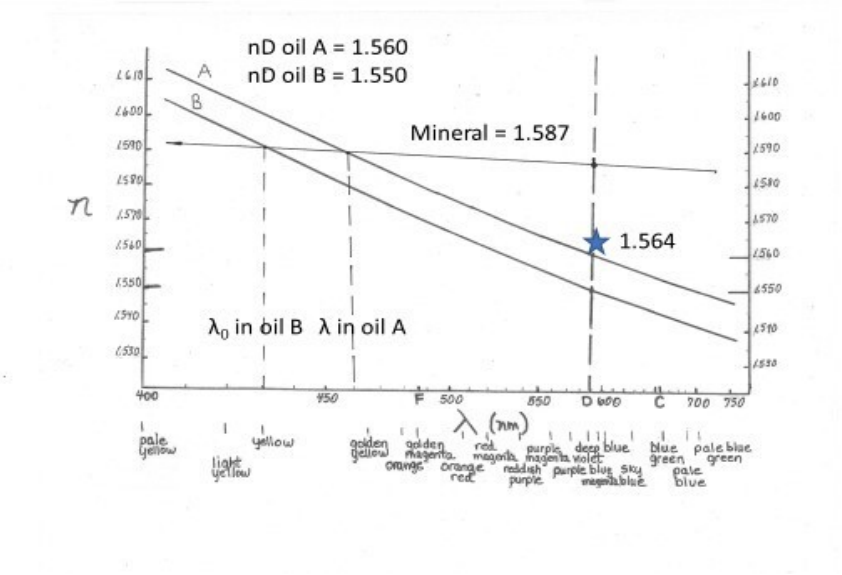


The dispersion staining colors have changed very little from those observed in 1.550 and λ_0 remains within the yellow range. MAS interprets this color as arising from a mineral with n = 1.564. However, the fact that the colors have changed very little makes this conclusion impossible because the dispersion curve must be fairly flat, as **Figure 12** shows.

In **Figure 12**, the λ_0's observed parallel to elongation in oils 1.550 and 1.560 are plotted.

Figure 12. Two λ_0s from two oils fix the mineral dispersion.

Observations in Oil A from Valadez Bot 2.28.23 and Oil B from AS Project M66515 – 001 CSM – 001. 2020: The dispersion curve parallel to elongation



The dispersion curve of the unknown must be flat to explain the fact that the observed dispersion staining colors change very little in the two oils. There is no reasonable explanation for the conclusion MAS makes that this mineral has an index of refraction of 1.564, which would require a dispersion approaching that of the oils.

In summary, the extrapolation from the observation of the dispersion staining colors in a **single** oil to a value of the index of refraction at the reference wave length cannot be made unless the dispersion of the mineral is known in advance. In this case, both talc and chrysotile have low dispersion and the indices of refraction MAS derived from the dispersion colors are inconsistent with its own observations. When the mineral is examined in two different oils, it is clear also that the MAS-reported indices of refraction are inconsistent with the data provided. Furthermore, the dispersion staining colors are indistinguishable from talc. In fact, the so-called chrysotile is actually talc.

F. Birefringence

MAS reports birefringence by subtracting the index of refraction it reports perpendicular to elongation from the index of refraction it reports parallel to elongation. Given that the indices of refraction are incorrect, this yields incorrect estimates of the birefringence. Alternate approaches to determining birefringence should have been used.

Although MAS did not consider an alternate approach to birefringence, as I mentioned early in this report, birefringence can be estimated ***independently*** from the values of the indices of refraction by an examination of the **retardation** observed when the mineral is in the 45-degree position and the second polarizer, the analyzer, is in the optical path and the central stop has been removed from the optical path[9].

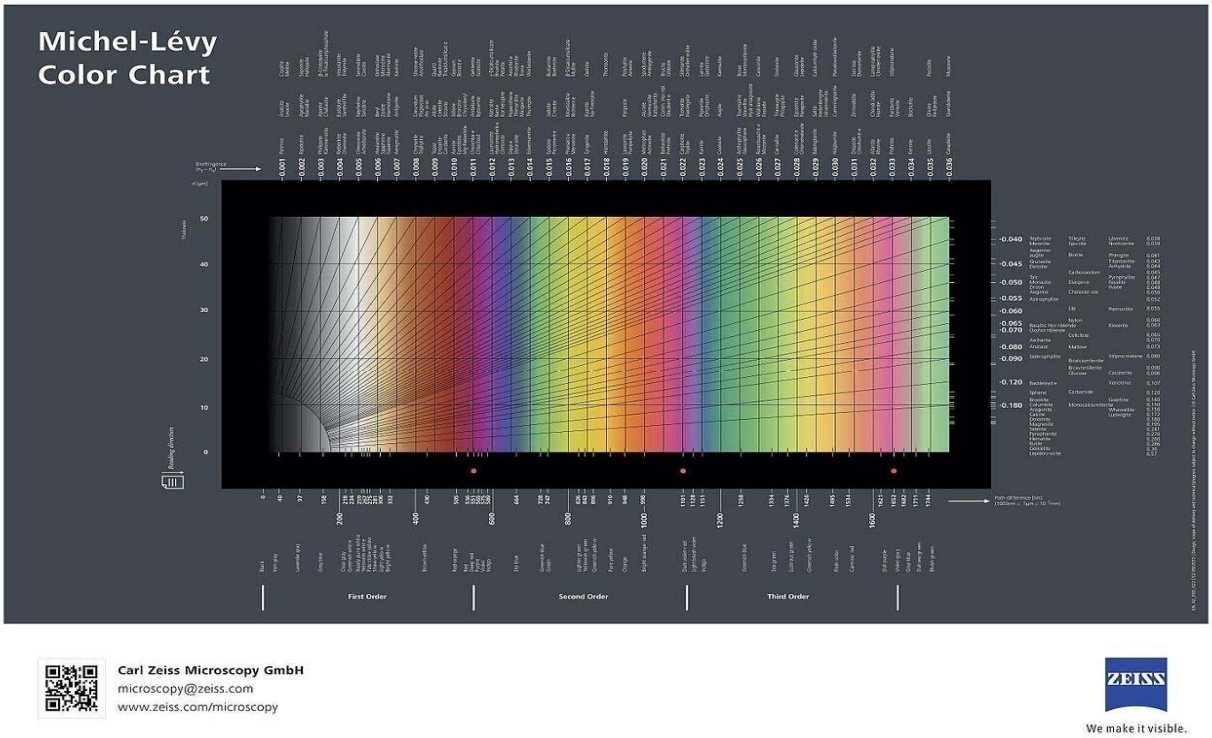
Retardation is a measure of the distance separating two rays that have travelled through the mineral at different speeds when they emerge from the mineral particle, one vibrating parallel to elongation and one vibrating perpendicular to elongation within the mineral. This distance, measured in nanometers, is a function of the speed of each ray, (i.e., index of refraction), and the distance of travel, which is the thickness of the mineral particle. This relationship is related by a simple formula.

$$\text{Retardation} = \text{thickness} (n_{\text{parallel}} - n_{\text{perpendicular}})$$

When the rays emerge, they combine and interfere, producing a color (like an oil sheen on water) called an interference color. Fortunately, all optical textbooks provide a chart, which I have reproduced in **Figure 13**. In this chart, the interference colors are shown. The distance separating the rays when they emerge is on the X axis, thickness on the Y axis and the interference color that corresponds to the retardation is shown. The radiating lines represent different amounts of birefringence.

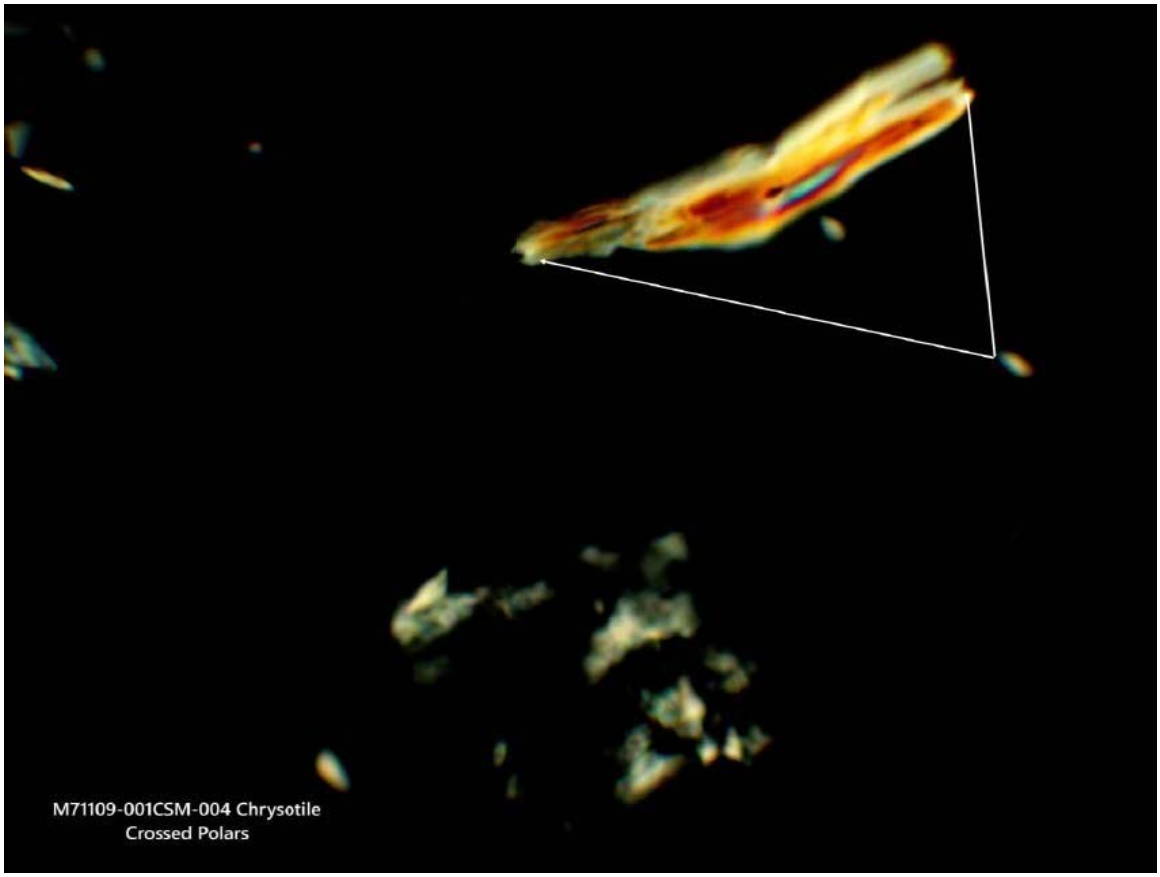
[9] Bloss, F. Donald, Optical Crystallography. MSA Monograph Series 5. Mineralogical Society of America, 1999, at p.117 and following.

Figure 13. The Michel Levy chart relating thickness, retardation, interference colors and birefringence.



The interference colors of particles that are very thin are hard to interpret because they are simply shades of grey, no matter how high the birefringence is, but in the MAS reports, there are many particles large enough that the birefringence can be estimated from the photographs provided. An example is shown in **Figure 14**. Other examples are provided in Appendix 2.

Figure 14. Particle identified as chrysotile in the 45-degree position with the polarizer and analyzer in the system.



The particle shown, identified as chrysotile by MAS, is 82.2 um long. It is about 16 µm wide. While we do not know exactly how thick it is, it is likely somewhat less than 16µm at its thickest point. The interference colors increase from the thin edges to the thickest middle, ranging from grey to Second Order blue, which from the Michel-Levy chart tells us that the retardation is about 650 nm. The means that the fast ray leaves the crystal 650 nm ahead of the slower ray. If this particle has a thickness equal to width, the interference colors require that the birefringence be at least 0.04. If it is thinner, the birefringence would be higher. A material with this birefringence cannot be chrysotile because the birefringence of chrysotile observed in samples from many locations is always < 0.017.[10] However, it is consistent with the birefringence expected for talc, which at its maximum is ≈0.05[11]. Had MAS evaluated the retardation of the particles it identified as chrysotile independently from the indices of refraction, it would have seen that the birefringence it derived from the indices of refraction was incorrect. Other examples are shown in Appendix 2.

[10] Deer, WA, Howie RA and Zussman J, Rock Forming Minerals Volume 3B second edition: Layered Silicates excluding micas and clay minerals. The Geological Society London, 2009.

[11] As is discussed later, orientation will affect the observed birefringence in talc. Parallel to elongation, the birefringence can range from < 0.01 up to 0.05. The talc particles MAS calls chrysotile are oriented in such a way that the birefringence is on the higher side.

G. Variation in the indices of refraction determined for the particles identified as chrysotile.

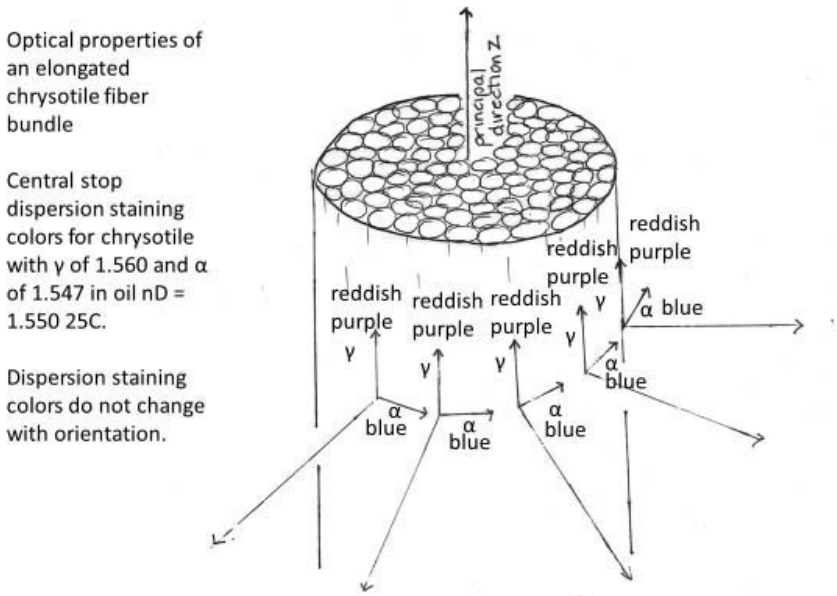
MAS incorrectly assumes that the indices of refraction of chrysotile can vary significantly in a single occurrence. Variations in index of refraction in chrysotile are due to variations chemical composition which are not known to occur in a single location.

In the MAS reports, a repeated claim is made that the variation in the indices of refraction observed and reported for the particles identified as chrysotile is consistent with the mineralogical literature for chrysotile (see, for example, the lab sheet shown in **Figure 19**, Comment section at the bottom). There are two reasons that particles of a single mineral can show a variation in index of refraction: particle orientation and variation in chemical composition. I will discuss these two independently as they apply to chrysotile and talc.

a. Orientation

Figure 15 is a schematic drawing of a bundle of chrysotile fibrils. Chrysotile occurs in nature in remarkably similar ways in all occurrences as bundles of single parallel cylindrical fibrils. Fibrils are tubes formed from cylindrical silicate sheets, commonly with an outer diameter of 0.025 to 0.030 µm and an internal diameter of about 0.005 µm. These individual fibrils are too small to see by light microscopy, so any visible particle of chrysotile will be composed of hundreds of parallel fibrils in bundles. Because of this, chrysotile particles will show no variation in dispersion staining colors perpendicular to elongation due to orientation.

Figure 15. Schematic view of a chrysotile fiber bundle showing consistency of dispersion staining colors with orientation.

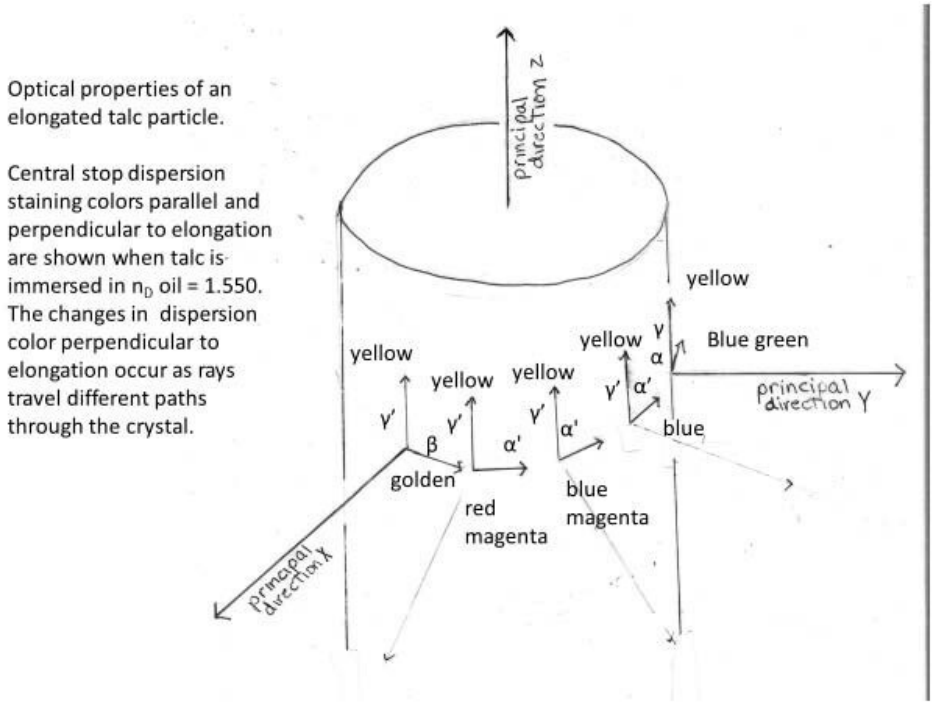


In contrast to chrysotile, **Figure 16** shows an elongated talc particle and the dispersion staining colors in Series E oil 1.550 parallel and perpendicular to elongation, ignoring in this case the small extinction angle normally present.

As **Figure 16** shows, the indices of refraction and associated dispersion staining colors of elongated talc particles perpendicular to elongation change significantly depending on how the particle is oriented. Because talc sometimes has a plane of weakness perpendicular to the direction Y, many will stain shades of blue perpendicular and yellow parallel to elongation, just as MAS reports for its "chrysotile" particles. A few of the particles identified as chrysotile stain reddish purple, indicating a slightly different orientation (See for example MAS 71109-71111)

It is common practice among optical mineralogists when observing particles immersed in oils to "tap the slide" to encourage particles to rotate around the long axis and to change orientation. In this way, if there are changes in dispersion staining colors as a function of orientation it is clear. This technique would have made the distinction between talc and chrysotile evident. There is no evidence that this simple technique was used. Instead, MAS assumed that variation in chemical composition accounted for the observed variation in dispersion staining colors.

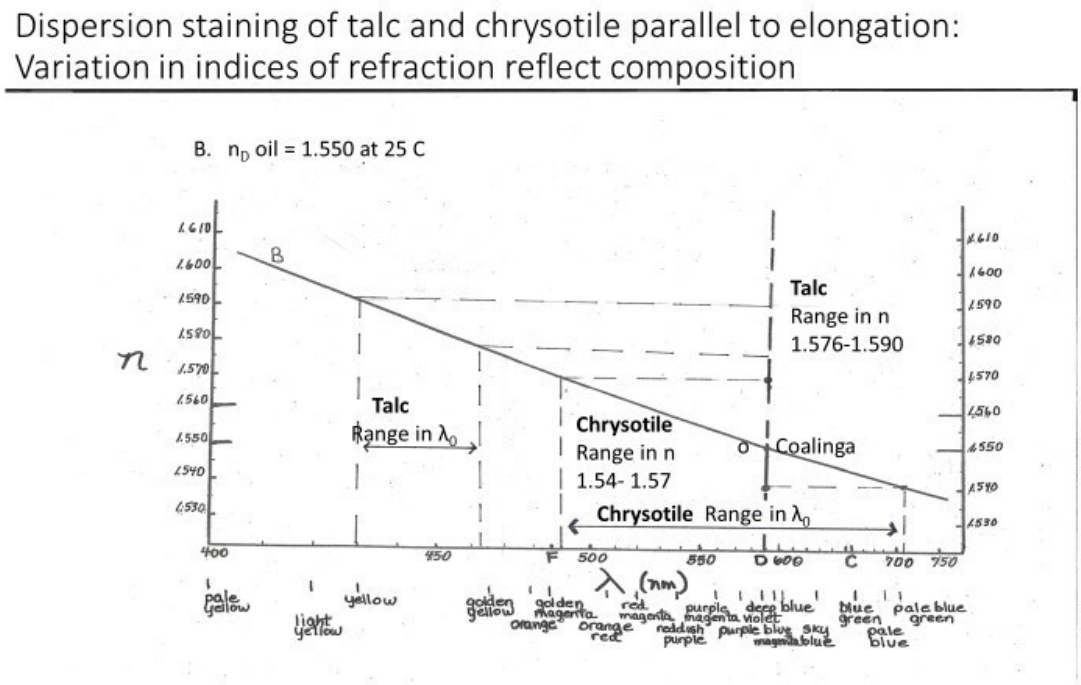
Figure 16: Dispersion staining colors and orientation: Talc with principal indices of refraction of 1.588 (gamma) and 1.547 (alpha)



b. Chemical composition

The ideal chemical formula for chrysotile is $Mg_3Si_2O_5(OH)_4$ and the ideal chemical formula for talc is $Mg_3Si_4O_5(OH)_2$. Small amounts of other elements substituting for magnesium (Mg) or silicon (Si) will change the optical properties. The most common substitution with a significant effect on the indices of refraction is iron (Fe). Because like Mg and Si, Fe is a common element, in some occurrences of these minerals it can have a significant impact. **Figure 17** shows the range in λ_0 and associated indices of refraction for talc and chrysotile parallel to elongation in Series E 1.550 oil due to differences in chemical composition. This figure considers the optical properties from many samples found throughout the world.

Figure 17. Range of principal indices of refraction parallel to elongation in talc and chrysotile due to chemical variability across all locations.[12]



The data that are illustrated in **Figure 17** are taken from many different geologic settings. Geologic conditions such as abundances of chemical elements, temperature and pressure are variables from one occurrence to another and result in the variation in composition. In some ways, every rock is unique because of the complexity and variability in the physical and chemical conditions under which they form. However, at each location, these conditions are usually the same, and the compositions do not change within a single location often.

Figure 18 gives the λ_0 in 1.550 Series E immersion oil for chrysotile occurrences throughout the world that was compiled by McCrone and published in his Particle Atlas. No variations are shown because chrysotile does not exhibit chemical variability within a single location that is significant enough to alter its appearance by dispersion staining. Each location has a characteristic composition. The assertion by MAS that the variations it observed are due to chemical variability is not supported by chrysotile from any other source and is directly contradicted by the data of McCrone. It is my opinion that the particles are talc, not chrysotile, and variations in dispersion staining colors can be explained by orientation.

[12] Deer, WA, Howie RA Zussman J, Rock-forming Minerals, Volume 3B. Layered silicates excluding micas and clay minerals. The Geological Society. London, 2009.

Figure 18. λ_0 for chrysotile in 1.550 Series E oil vary only by location from McCrone, 1980[13].

McCrone Asbestos Particle Atlas Table 5

Location	$\lambda_0 \parallel$	$\lambda_0 \perp$	$\lambda_0 \perp$-$\lambda_0 \parallel$	Location	$\lambda_0 \parallel$	$\lambda_0 \perp$	$\lambda_0 \perp$-$\lambda_0 \parallel$
Lake Asbestos Quebec	510	610	**100**	Pacific Asbestos Corp CA	480	610	**130**
King Asbestos Corp Quebec	510	510	**100**	**Coalinga CA**	**590**	**680**	**90**
Asbestos Corp Quebec	500	610	**110**	Arizona	600	700	**100**
Bell Mines Quebec	510	600	**90**	Venezuela	610	680	**70**
Johnsons Quebec	500	600	**100**	Rhodesia	520	620	**100**
Careys Bradford Quebec	480	590	**110**	Shabina Rhodesia	480	580	**100**
Flintkote Quebec	500	610	**110**	Havelock D &C Rhodesia	490	590	**100**
Normandie Quebec	570	670	**100**	Havelock HVL Rhodesia	490	590	**100**
Reeves Ontario	480	590	**110**	Havelock VRA Rhodesia	500	630	**130**
Munro Ontario	560	670	**110**	Cyprus	600	700	**100**
Hyde Park GAF Vermont	510	620	**110**	Zandini Greece	580	680	**100**
Jeffery Vermont	500	580	**80**	Yugoslavia	520	590	**70**
Advocate Newfoundland	510	610	**100**	Balengero Italy	500	600	**100**
Newfoundland	590	690	**100**	Russia	500	600	**100**
Clinton Creek Yukon	500	580	**80**	Woodsreef Australia	610	680	**70**
Cassiar British Columbia	500	580	**80**				

H. Birefringence observations from λ_0 from McCrone (Figure 18) and MAS data particles identified as chrysotile.

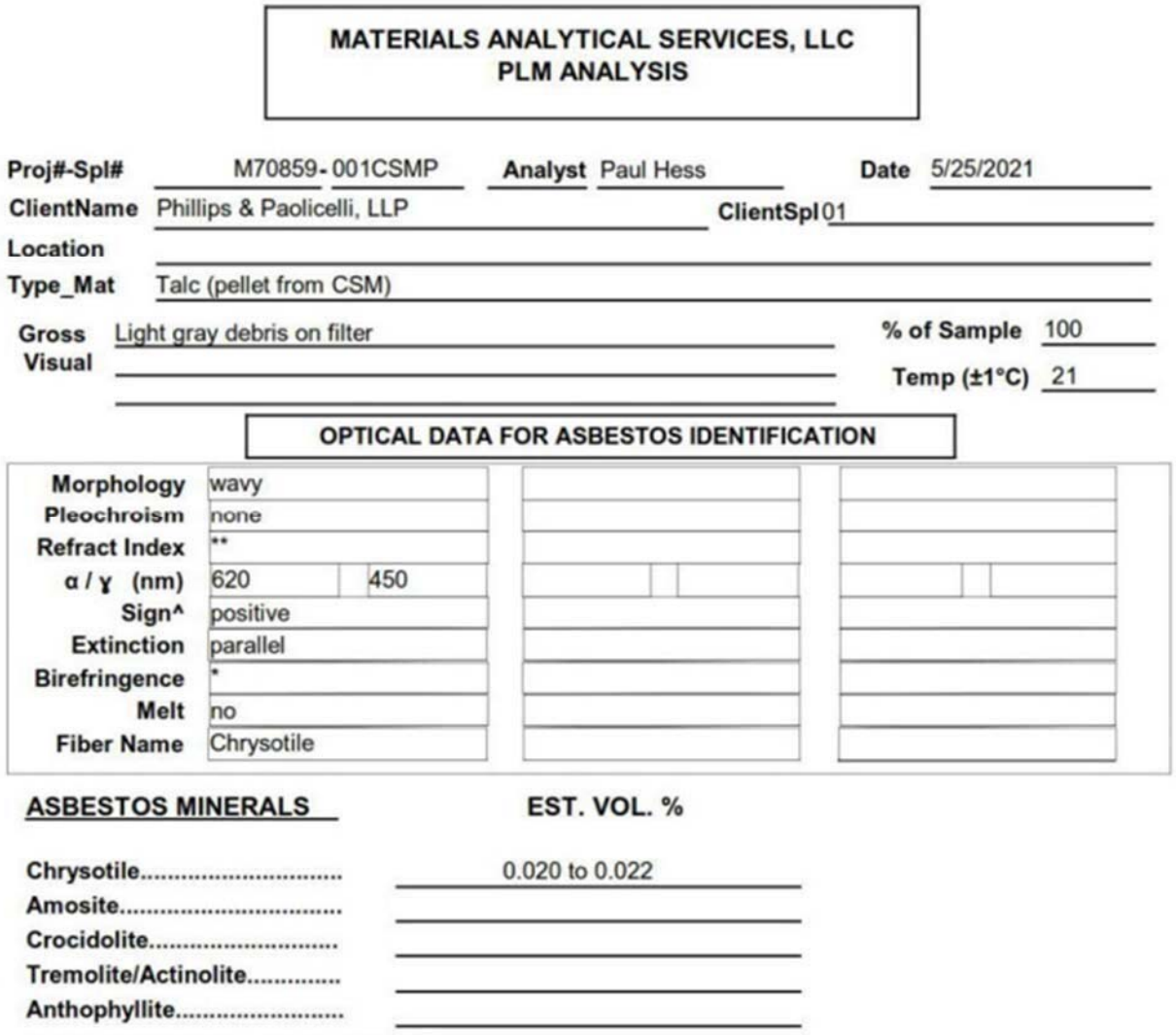
MAS's own data on λ_0 are inconsistent with data on chrysotile from McCrone but consistent with talc.

An important observation from **Figure 18** is that the differences in λ_0 parallel and perpendicular to elongation are small, and no range is provided. Most differences are less than 110 and all are less than 130 nm. This limitation reflects the birefringence of chrysotile: it does not vary with location and it is small. ISO Method 22262-1 for the identification of chrysotile in building materials, which MAS states it follows, specifies that the difference should be no more than 100 nm for chrysotile. The majority of the particles identified as chrysotile by MAS have values of λ_0 parallel – λ_0 perpendicular that vastly exceed this value, and even exceed the highest value given by McCrone from any chrysotile, including Coalinga (also known as Calidria). In many of the MAS laboratory sheets, this is made clear. For example, Figure 19 reproduces two of those sheets. Under the column labeled Optical data, α/δ (nm), in the first the numbers 640 and 450 appear, and in the second, 640 and 450. These are the λ_0's that MAS determined from the observed dispersion staining colors perpendicular and parallel to elongation of the particle identified as chrysotile. Where such data are included in other reports, these values are typical. They are much greater than 110 nm apart, indicating a

[13] McCrone, W., The Asbestos Particle Atlas. Ann Arbor Science Publishing Inc. Ann Arbor Michigan, 1980. To his data for λ_0, I added the column showing the difference. In two locations identified by McCrone as Rhodesian and Italian; Balengera, a second set of λ0's is given suggesting a second period of crystallization under somewhat different conditions. There are no ranges given, however, so the chrysotile from these two locations has optical properties of one or the other with none in between.

birefringence (as determined in this way) that is too high for chrysotile and inconsistent with the ISO 22262-1.

Figure 19. Representative MAS data sheets for PLM analysis



MATERIALS ANALYTICAL SERVICES, LLC
PLM ANALYSIS

Proj#-Spl#	M70859-001CSMP	**Analyst**	Paul Hess	**Date**	5/25/2021
ClientName	Phillips & Paolicelli, LLP	**ClientSpl**	01		
Location					
Type_Mat	Talc (pellet from CSM)				
Gross Visual	Light gray debris on filter			**% of Sample**	100
				Temp (±1°C)	21

OPTICAL DATA FOR ASBESTOS IDENTIFICATION

Morphology	wavy		
Pleochroism	none		
Refract Index	**		
α / γ (nm)	620 / 450		
Sign^	positive		
Extinction	parallel		
Birefringence	*		
Melt	no		
Fiber Name	Chrysotile		

ASBESTOS MINERALS	**EST. VOL. %**
Chrysotile	0.020 to 0.022
Amosite	
Crocidolite	
Tremolite/Actinolite	
Anthophyllite	

MATERIALS ANALYTICAL SERVICES, LLC
PLM ANALYSIS

Proj#-Spl#	M71211- 007CSMP	**Analyst**	Paul Hess	**Date**	5/14/2021
ClientName	Weitz & Luxenberg PC	**ClientSpl**	20200342-07		
Location	Date code on Original Container: 0680ZA3 00:55				
Type_Mat	Johnson's baby powder				

Gross Visual debris on filter

% of Sample 100

Temp (±1°C) 21

OPTICAL DATA FOR ASBESTOS IDENTIFICATION

Morphology	wavy		
Pleochroism	none		
Refract Index	**		
α / γ (nm)	640 / 450		
Sign^	positive		
Extinction	parallel		
Birefringence	*		
Melt	no		
Fiber Name	Chrysotile		

ASBESTOS MINERALS	**EST. VOL. %**
Chrysotile	0.010 to 0.013
Amosite	
Crocidolite	
Tremolite/Actinolite	
Anthophyllite	

OTHER FIBROUS COMPONENTS

NON FIBROUS COMPONENTS

Talc	X
Mineral grains	X

Comments Chrysotile asbestos observed. ** Refractive indices parallel were 1.559(513nm) to 1.568(450nm). Refractive indices perpendicular range 1.548(640nm) to 1.554(570nm). *Birefringence from low to moderate. X=Materials Detected. 35 Chrysotile structures, inclusive of those documented by photograph, counted in 30 fields of view. Equates to 1.5 structures per square millimeter.

The method detection limit is 1% unless otherwise stated.

In two reports, M71262 and M70859, the values of λ_0 parallel and perpendicular were determined by MAS for many samples; these data are compiled in **Figure 20**. There are two observations that can be made from these data.

First, λ_0 parallel is lower than almost all of the chrysotile λ_0 from McCrone and λ_0 perpendicular to elongation is higher. The difference between the two is in all cases greater than 130 nm, indicating a birefringence higher than that of all other reported chrysotile.

Second, the values given by MAS for λ_0 parallel to elongation are outside the range known for chrysotile as shown in **Figure 17** but instead fall within the range expected for talc.

Taken together, these two observations demonstrate that all particles identified in these two samples are talc, not chrysotile.

Figure 20. λ_0 perpendicular and parallel to elongation from the Optical Data sheets in MAS Reports M70859 and M71262 and working temperature in degrees centigrade. Both samples were examined in Series E 1.550 immersion oils.

	Sample	λ_0 Perpendicular (nm)	λ_0 Parallel (nm)	T
a. M70859				
	001CSMP	620	450	21
	002CSMP	600	455	21
	003 CSMP	850*	455	21
	004 ISO	620	455	21
	005 CSMP	590	445	21
	006 CSMP	640	455	21
	007 CSMP	600	450	21
	008CSMP	640	455	21
	009CSMP	600	455	21
b. M71262				
	001ISO	595	450	22
	001CSM	595	450	20
	002ISO	610	450	22
	002CSM	610	450	20
	003 ISO	630	470	22
	003CSM	630	470	20
	004 ISO	650	450	21
	004 CSM	630	450	20
	005ISO	640	460	21
	005CSM	600	450	21
	006ISO	620	450	21
	006CSM	750	460	21

λ_0 between 590 and 650 will appear blue to blue green and λ_0 between 445 and 470 will appear yellow to golden yellow. These are the two most common colors shown in the dispersion staining photographs of the minerals identified as chrysotile by MAS in all reports.

G. Coalinga (Calidria)

Coalinga chrysotile does not have optical properties consistent with those of the particles MAS identifies as chrysotile.

I have examined the Coalinga chrysotile, which in its report on this material MAS asserts is like the chrysotile it finds in Johnson & Johnson talc products. The Coalinga chrysotile product is a mineralogically complex material and contains minerals other than chrysotile as shown in **Figure 21**. The optical data MAS has presented for the Coalinga chrysotile is not for chrysotile at all, but rather one of the other minerals present, such as pyroaurite and/or brucite. This misidentification is likely due to both a misinterpretation of dispersion staining colors and ignoring other defining characteristics that could be determined by a comprehensive mineralogical examination, considering all factors described under Section A of this report. Furthermore, Coalinga chrysotile stains blue and blue magenta in 1.550 Series E oils, a fact seemingly overlooked by MAS.

Figure 21. Minerals known from Coalinga (Calidria)[14]

Mg Silicates, hydrates, and carbonates. Optical properties

The range in gamma and alpha Longo has matched to chrysotile from Calidria are: Gamma (1.57-1.55) and alpha (1.56-1.54). According to his logic, as long as N and n each fall somewhere within their respective range, he was satisfied with his identification. The following minerals may occur with chrysotile in Calidria materials:

Antigorite $Mg_3Si_2O_5(OH)_4$ alpha is 1.56-1.57 and gamma is 1.56 and 1.58.

Lizardite. $Mg_3Si_2O_5(OH)_4$. Alpha is 1.54 to 1.56 and gamma is 1.55 to .57

Pyroaurite $MgCO_{3.5}Mg(OH)_{22}Fe(OH)_3.4H_2O$ uniaxial negative $\omega = 1.564$ $\varepsilon = 1.543$ (fragments length slow)

Sjogrenite $MgCO_{3.5}Mg(OH)_{22}Fe(OH)_3.4H_2O$ uniaxial negative $\omega = 1.573$ and $\varepsilon = 1.559$ (fragments length slow)

Sepiolite- $Mg_4Si_6O_{15}(OH)_2.6H_20$ alpha from 1.498-1.522 and gamma 1.527-1.579. fibrous.

Stevensite $Mg_3Si_4O_{10}(OH)_2$ alpha = 1.500-1.560 and gamma = 1.510 to 1.570 depending on compositional substitutions for Mg. Brucite ($Mg(OH)_2$) uniaxial positive with $\varepsilon = 1.580$ and $\omega = 1.560$. (Fibers length slow; fragments length fast)

[14] Mumpton, FA and Thompson CS, Mineralogy and origin of the Coalinga asbestos deposit. In Clays and Clay minerals 23:131-143. 1975.

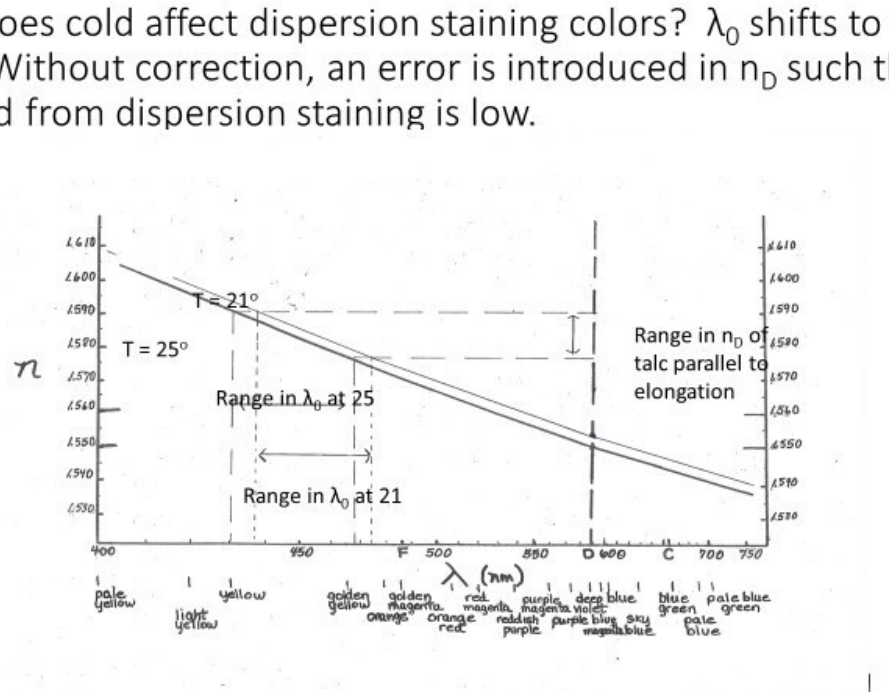
H. Temperature corrections lacking.

Changes in temperature affect dispersion staining colors but there is no evidence that MAS considered this error.

In many reports, especially the earlier ones, no laboratory temperature at the time of observation is recorded. Without consideration of temperature, a significant error in the determination of the index of refraction can result because of changes in the dispersion staining colors. **Figure 19** shows the MAS laboratory data sheets, in which a temperature of 21 degrees is recorded. In **Figure 22**, the impact of temperature is illustrated.

Low temperatures cause the oils to thicken and thereby increase their index of refraction. On every bottle of immersion oil, Cargille provides an estimate of how much. For 1.550 Series E, it can increase 0.0005 for every degree change below 25 C, the standard reference temperature. At a four-degree decrease (25-21), the indices of refraction of the oil 1.550 will actually be 1.552. In my own laboratory, we kept a thermocouple to measure temperature right in the oil mount when we wanted high precision in the measurement of the indices of refraction. Changing temperatures has no impact on the indices of refraction of minerals.

Figure 22. The effect of temperature on the index of refraction of immersion oils.



If λ_0 were determined at 21 degrees but no corrections were applied and the dispersion staining colors were interpreted for 25 C, a derived value of 1.585 would actually correspond to a value of 1.583 because λ_0 shifts to the right. For a mineral with higher dispersion, the shift of λ_0 would be greater and the error introduced higher. As the dispersion of the mineral increases, the error introduced increases.

Differences in index of refraction of this magnitude are meaningful differences in the world of mineralogy. By careful work, the index of refraction can be measured to a precision of ± 0.0005, so an error of 0.002 is very large. Measurement and correction for temperature is standard

procedure in optical mineralogy, yet there is no indication if or how temperature corrections were made in the MAS reports.

I. Morphology of Asbestos

The particles identified by MAS do not have the morphology of chrysotile asbestos.

EPA method 600[15] and ISO 22262-1 both provide criteria for the recognition of the habit of asbestos as observed by optical microscopy. They include a high aspect ratio (length/width) with a mean of about 20:1 and the presence of bundles that show evidence of splitting into very thin fibrils. The morphological properties of particles that have been identified by MAS as chrysotile are not characteristic of the properties of asbestos as described in these documents and or from my own experience. Because of the small chrysotile fibril width, usually < 0.030 µm, every particle identified as chrysotile would have to have be a bundle because individual fibrils cannot be seen by optical microscopy. Most of the particles MAS calls chrysotile could not be described as fibrous at all. The pattern of interference colors produced when the mineral particle is in the 45-degree position and both the polarizer and the analyzer are in the optical path, displays distinctive properties if the particle is a bundle of fibrils; such properties were not characteristic of the particles identified as chrysotile. Fiber bundles give distinctive interference figures, but there is no evidence that interference figures were observed, despite the fact observation of interference figures is always recommended for identification of birefringent minerals by polarized light.

J. Relief and Becke lines

Relief of particles identified as chrysotile is consistent with talc and inconsistent with chrysotile.

Relief is a qualitative term that describes the depth of shadows of the mineral grain when it is observed under the microscope without the dispersion staining objective or the analyzer in the optical path. For every particle that MAS provides a picture of the dispersion staining colors, a picture of the grain that demonstrates relief is also provided. **Figure 24** from Bloss provides an illustration of how relief is described. It can be low, medium, high, or very high. The relief changes as the difference between the mineral grain and the oil change, with maximum relief observed when the differences are very high and low relief when the differences in indices of refraction are small.

Figure 25 is an example taken from an MAS report. Other examples are provided in Appendix 3. The indicated particle is supposed to be chrysotile, while the other particles are talc. The colored fringes around the particles are Becke lines, another indication of the differences in indices of refraction between the mineral particles and the immersion oil in which they are mounted. In both relief and in the color of the Becke lines, the indicated particle cannot be distinguished from the talc particles. Were it actually chrysotile, this would not be the case.

[15] Perkins RL and Harvey BW, Test Method: Method for the determination of asbestos in bulk building materials. USEPA/600/R-93/116, 1993.

Relief and Becke lines of talc will vary with orientation and for that reason relief and Becke lines will vary somewhat. This is not the case for chrysotile, for which indices of refraction are not affected by orientation.

Figure 24. Relief of mineral grains vary.

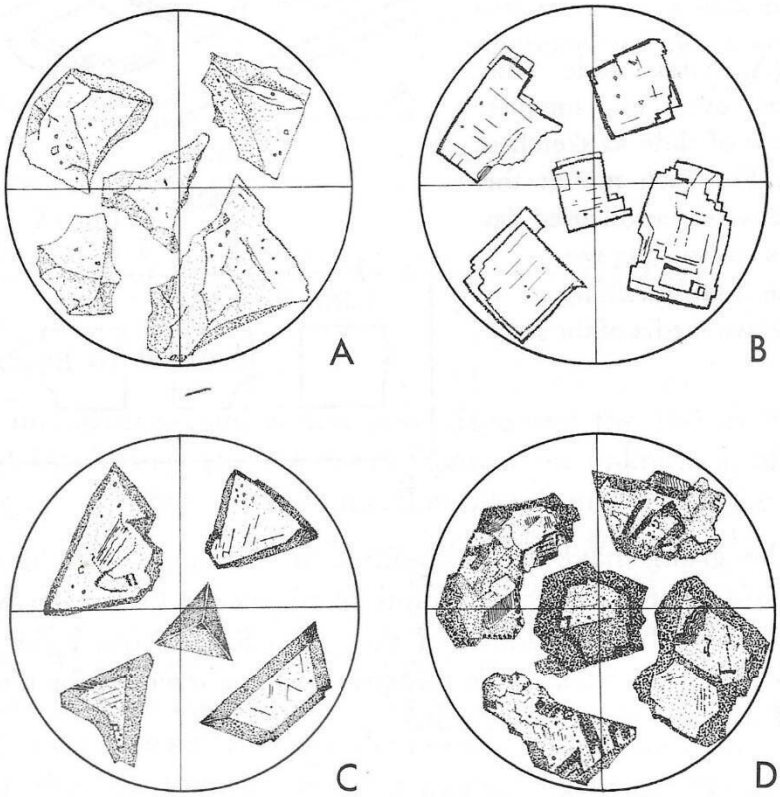
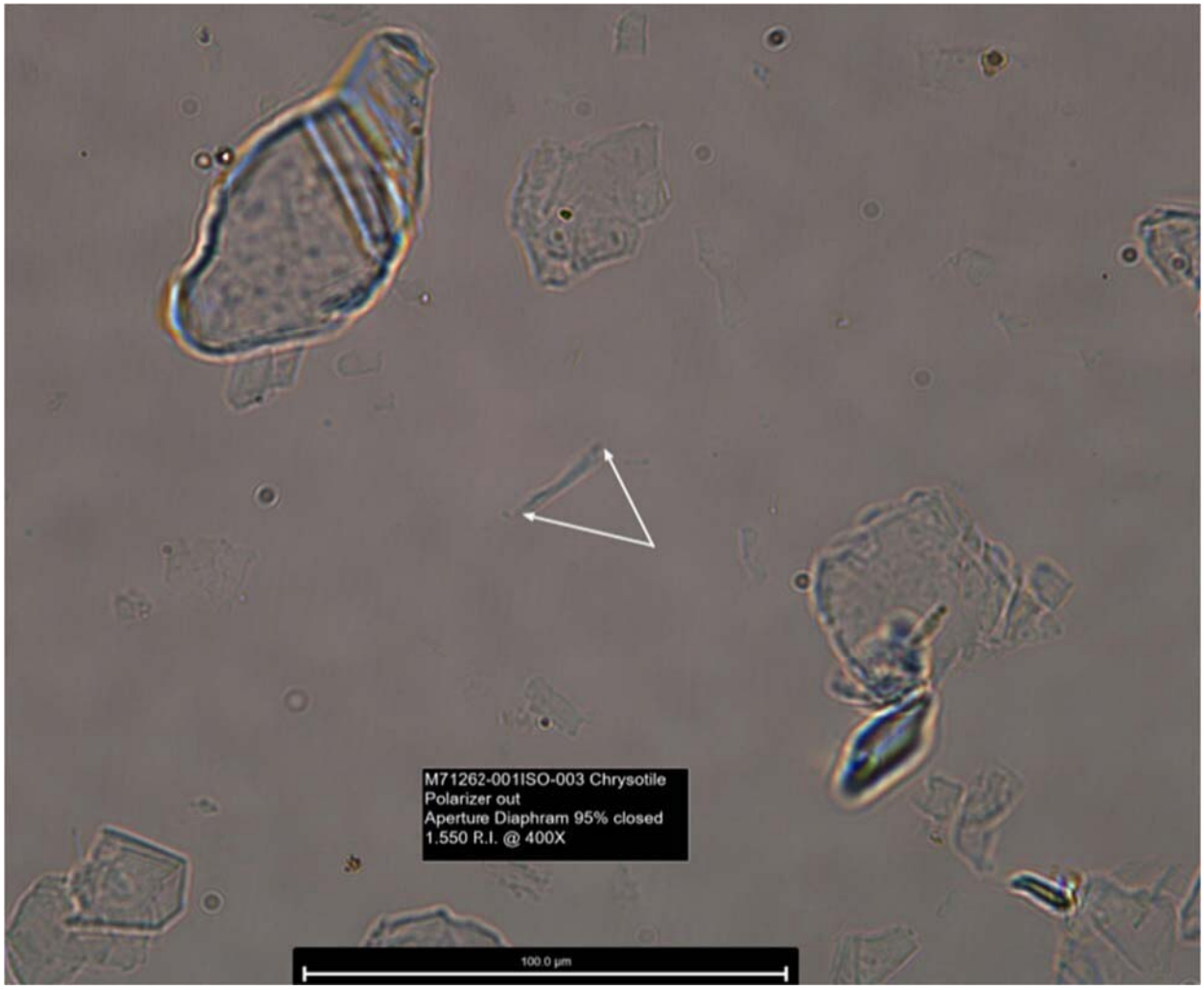


Fig. 5-12. Breakage types commonly seen on crushed isotropic grains: (A) conchoidal fracture but no cleavage; (B) cubic cleavage {100}—that is, three mutually perpendicular directions of equal ease of cleavage; (C) octahedral cleavage {111}—that is, four directions of equal ease of cleavage that are parallel to the faces of an octahedron; (D) dodecahedral cleavage {110}—that is, six directions of equal ease of cleavage parallel to the faces of the dodecahedron. Note that for dodecahedral cleavage the fact of six "competing" directions for cleavage makes it unlikely that a particular direction will be extensively developed; instead, the breakage surface alternately follows one and then another of these six directions. The relief of these grains in oil varies as follows: (A) low, (B) moderate, (C) high, (D) very high.

Figure 25. Typical photomicrograph illustrating relief. MAS has called the designated particle chrysotile. Note the similarity in relief and Becke lines to the particle on its right.



K. Other issues

ISO 22262-1 Method specifies that samples should be heated to 485 degrees C before examination. We know that chrysotile is stable at these high temperatures, but they are high enough to remove organic fiber that may have contaminated talc powders. Some of these organic fibers can be confused with chrysotile. In the reports, MAS says it heated the samples but the temperatures given are variable, and include 400C, 425C, 480C, and 400F. It is not clear why MAS does not follow the recommendations of the ISO method.

In MAS Supplemental Report 07.31.23, MAS describes milling a NIST chrysotile standard to more closely resemble the particle sizes of talcum powder. MAS seems to believe that size reduction changes the indices of refraction.

> "MAS has recently completed a study were the NIST chrysotile standard was milled with liquid nitrogen ball mill to reduce the size of chrysotile bundles to a 200 sieve. The talc particle size standard for cosmetic talc is a -200 sieve. Our results showed that when the 1866b chrysotile bundles were reduce in length and thickness that was consistent with both the SG-210 and the cosmetic talc chrysotile bundles, the CSDS (central stop dispersion staining) colors are consistent with both the SG-210 and cosmetic talc chrysotile."

Unless size reduction alters the atomic structure of the material, which is unlikely if grinding is done under liquid nitrogen as described, indices of refraction and associated dispersion staining colors will not change. Index of refraction is dependent on the atomic structure and chemical composition, neither of which is normally altered by size reduction. Ball milling can be destructive to the atomic structure of minerals if it persists for many hours, but details of this "study" are not provided.

In that same Supplemental Report 07.31.23, MAS states that the difference in observing talc powder in Series E 1.560 vs 1.550 is that the

> "measured refractive indices for the 1.560 RI Fluid were closer together for the alpha and gamma directions, which caused the BIR calculations to be all in LOW range with an overall average of 0.006 versus 0.010-0.013 range typically seen using 1.550 RI fluid."

This statement implies either that the indices of refraction and birefringence change depending on the immersion oil, which is not true, or it is a recognition that calculated birefringence MAS has tabulated from its 1.550 studies are incorrect.

Chrysotile fibrils are most readily identified by transmission electron microscopy (TEM). Their chemical composition in combination with their tubular morphology and small widths make identification by TEM very reliable. Why MAS did not use TEM to confirm the presence of chrysotile in all samples is not clear. Were I concerned about the presence of chrysotile, I would certainly use TEM and not light microscopy. Where MAS did use TEM, it did not report chrysotile, strong evidence that it is not present.

Summary

In conclusion, I do not see any evidence in the reviewed MAS reports that any chrysotile fibers were identified in the samples.

MAS does not consider the full range of optical properties that are standard and necessary to identify unknown minerals. Had they, it would have been clear that the mineral particles they identify as chrysotile are talc.

MAS misinterprets the dispersion staining colors of some elongate talc particles to produce values of the index of refraction parallel and perpendicular to elongation that are incorrect and inconsistent with the dispersion staining colors.
MAS relies on the incorrectly derived indices of refraction to determine an incorrect birefringence and does not consider other types of optical data that could be used to demonstrate this error.

The differences in λ_0 parallel and perpendicular to elongation are inconsistent with chrysotile and do not conform to the values specified for the identification of chrysotile by ISO 22262-1.

MAS assumes that the range in the dispersions staining colors observed from the particles they identify as chrysotile is due to chemical compositional variation in chrysotile. Chrysotile from different locations (with different physical and chemical conditions governing formation) may vary among occurrences, but available published data show that within a single occurrence, they do not occur with a range of values. The variation MAS reports in dispersion staining colors is due to variations in the orientation of talc particles.

MAS does not correct for temperature which changes the index of refraction of the immersion oils used, introducing error and compromising an accurate determination of index of refraction.

MAS provides pictures of particle relief, but does not consider them. These pictures demonstrate that the relief of the particles indicated as chrysotile varies very little from talc particles and if there is a variation, it can be explained by orientation.

The particles identified by MAS do not have the optical or morphological characteristics of chrysotile fiber bundles.

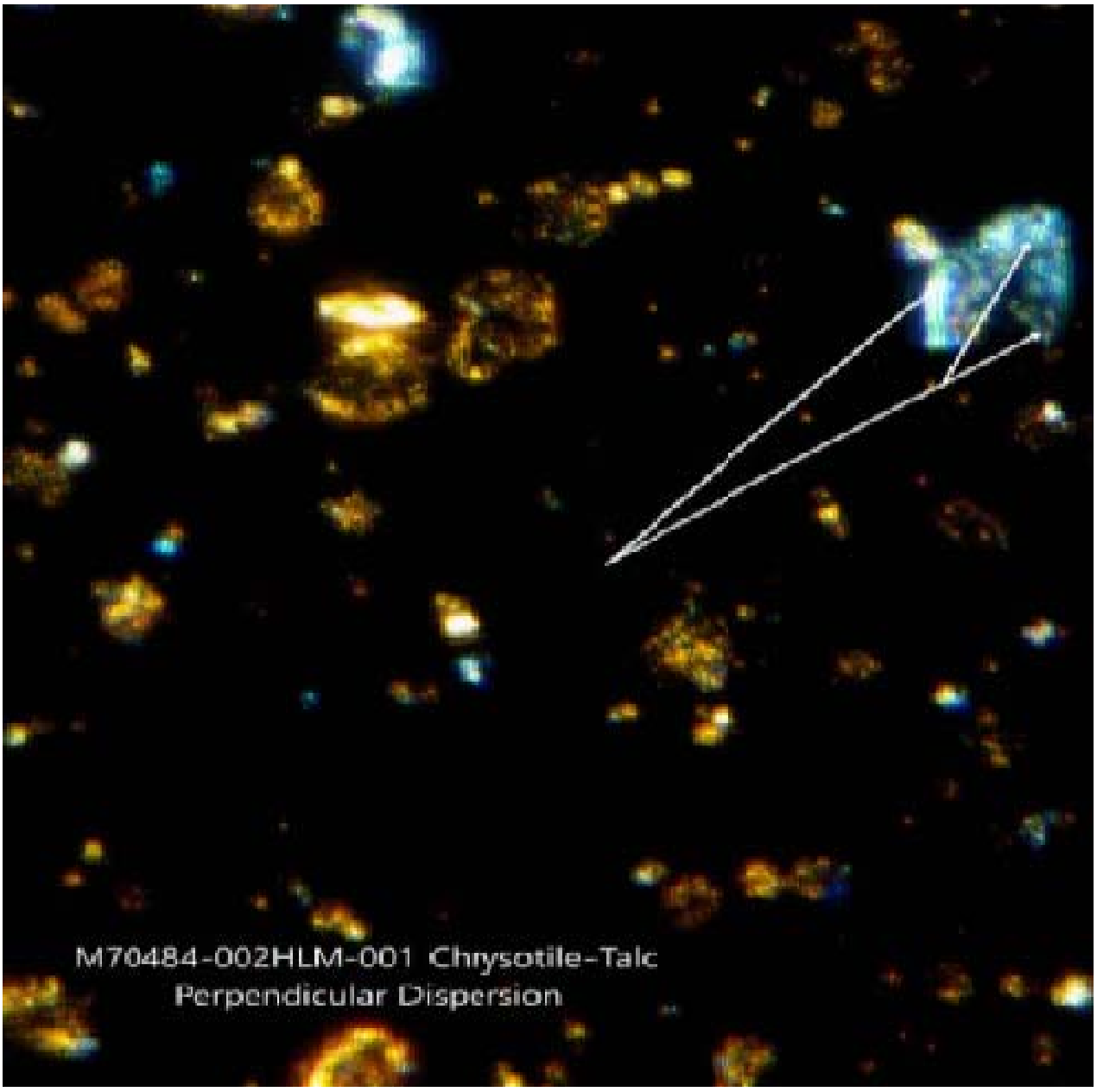
Other errors in the reports demonstrate inconsistent laboratory practices and misunderstanding of how optical properties can be affected by sample preparation for examination by PLM.

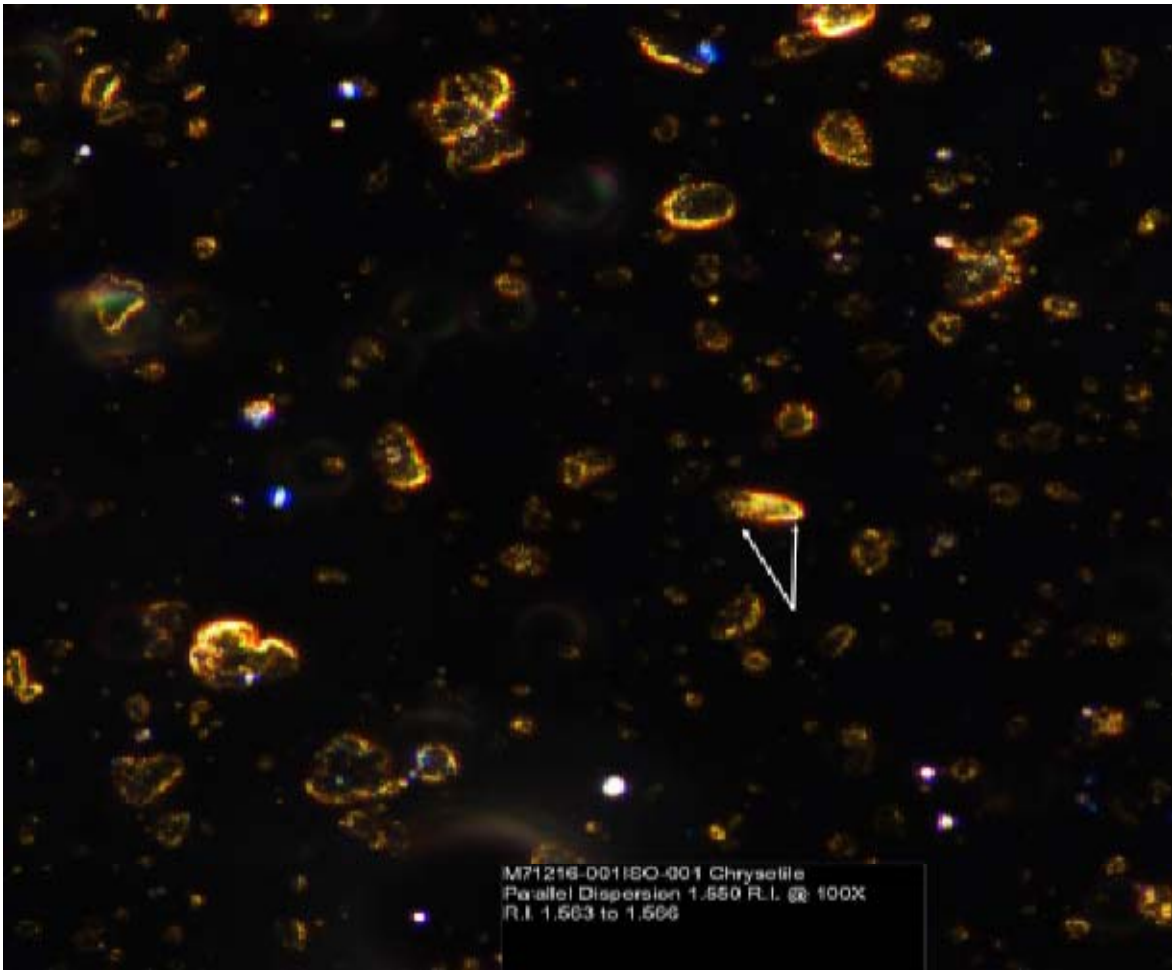
The lack of collaboration of the presence of chrysotile by TEM by a laboratory with TEM capabilities and experience is consistent with its absence.

Ann G. Wylie, Ph.D.

Appendix 1.

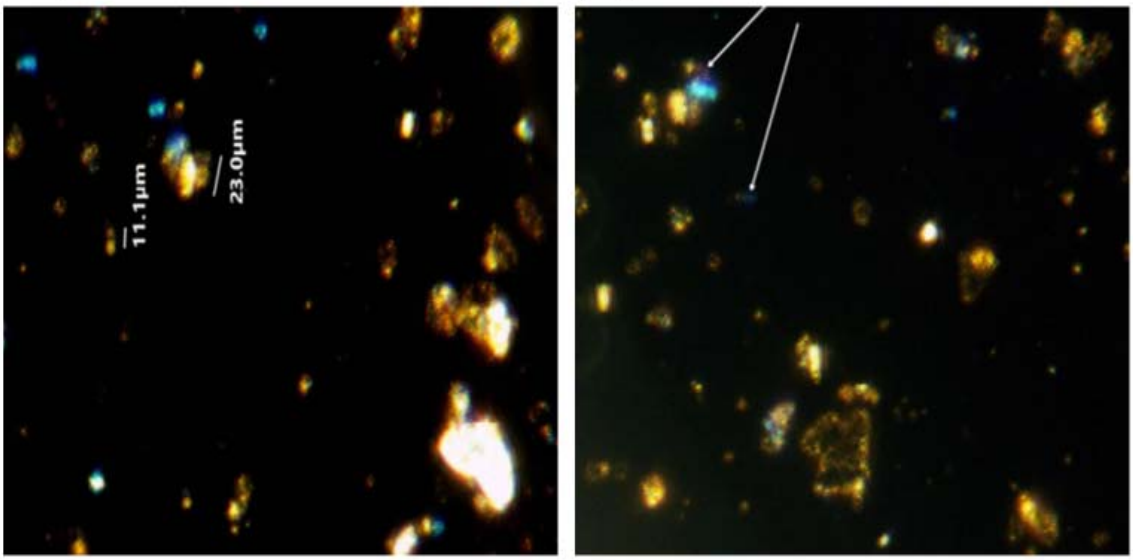
Additional examples of dispersion staining colors that are characteristic of talc but not chrysotile. Two orientations are shown: one with vibration direction of light parallel or near parallel to elongation (yellow) and perpendicular to elongation (blue). Note other particles not identified as chrysotile by MAS by arrows with the same dispersion staining colors. They are talc.

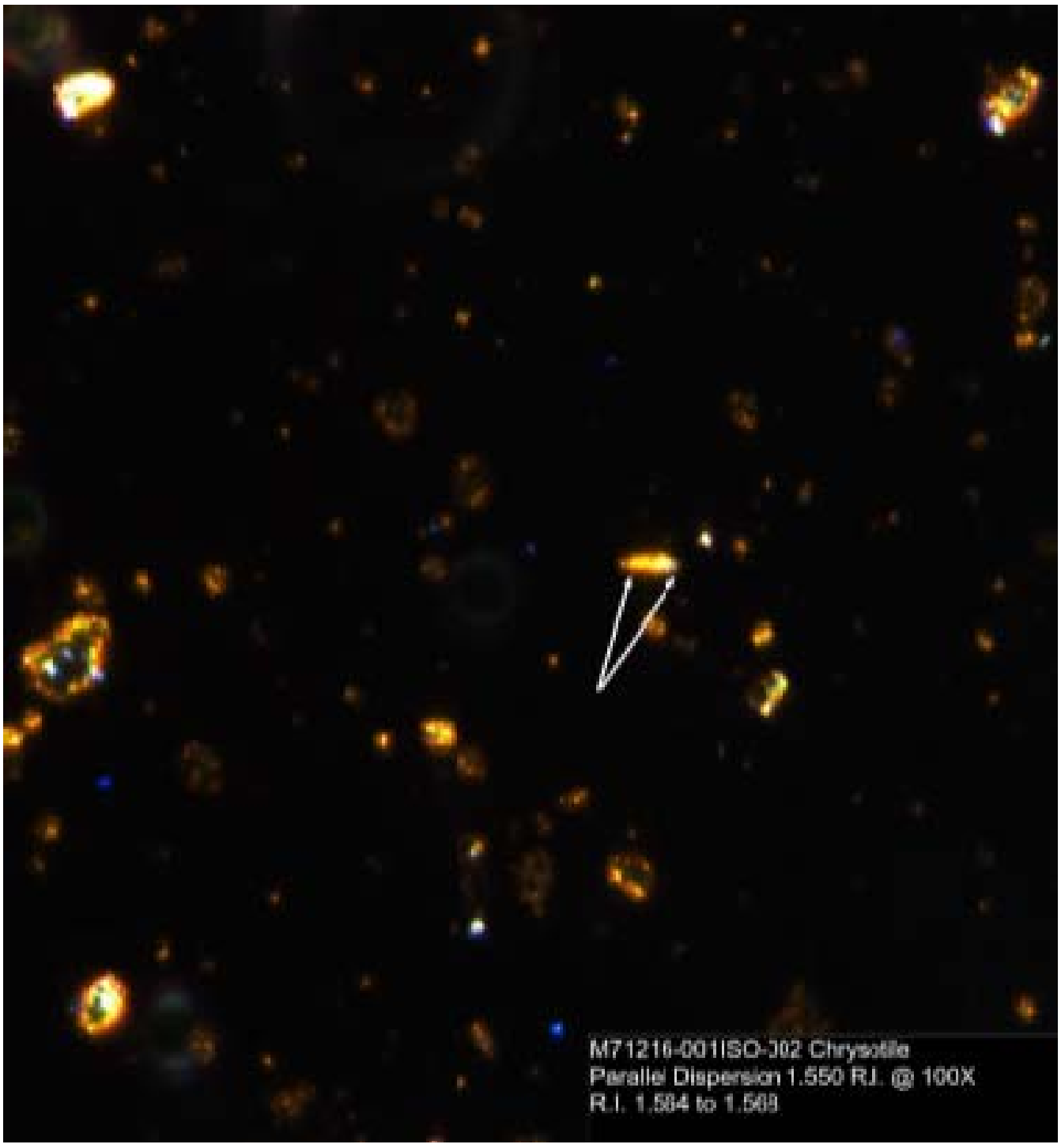


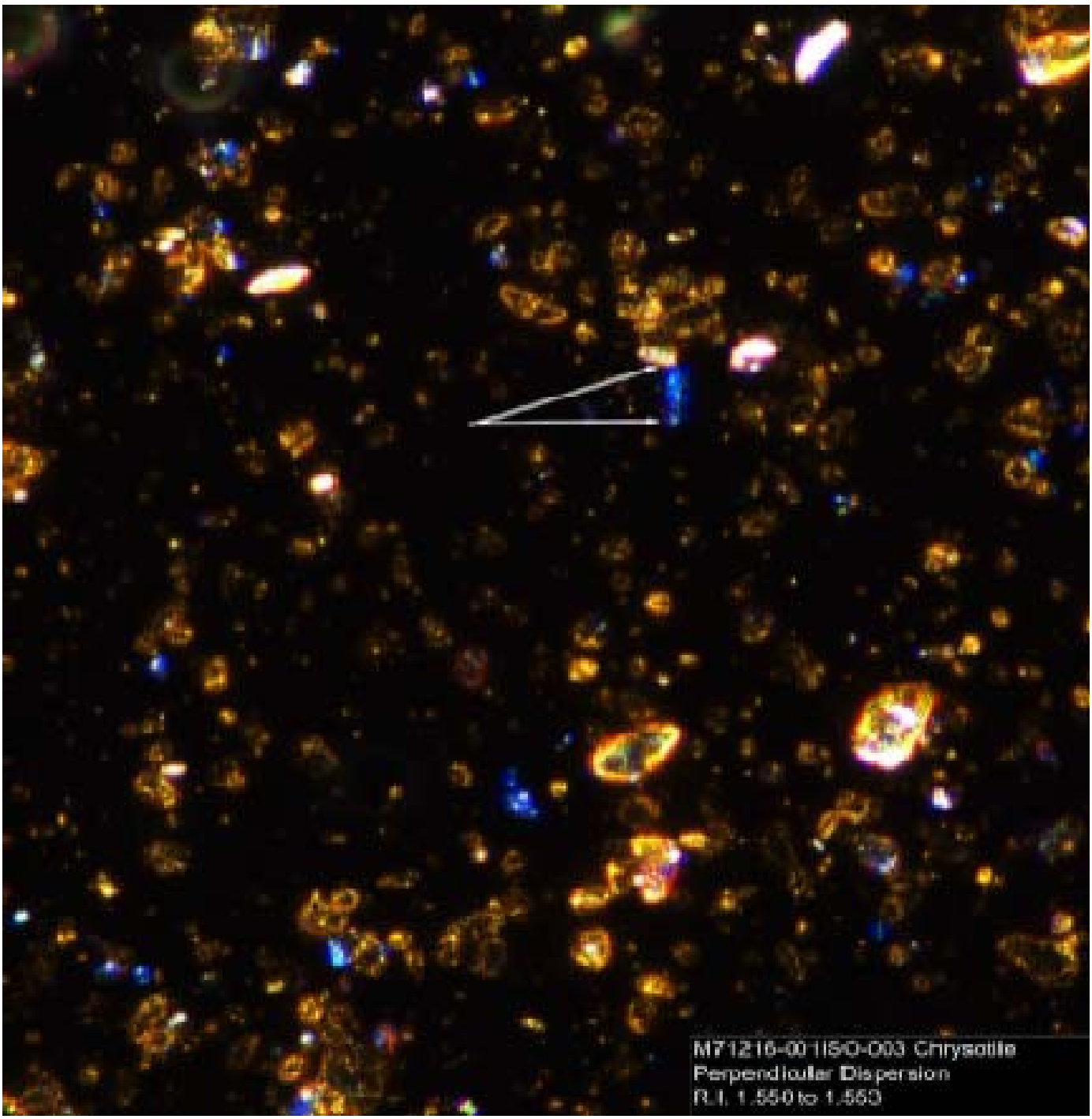


MAS70877.001CMS – 003 1.550 oil. Two particles identified as chrysotile by MAS

parallel **perpendicular**

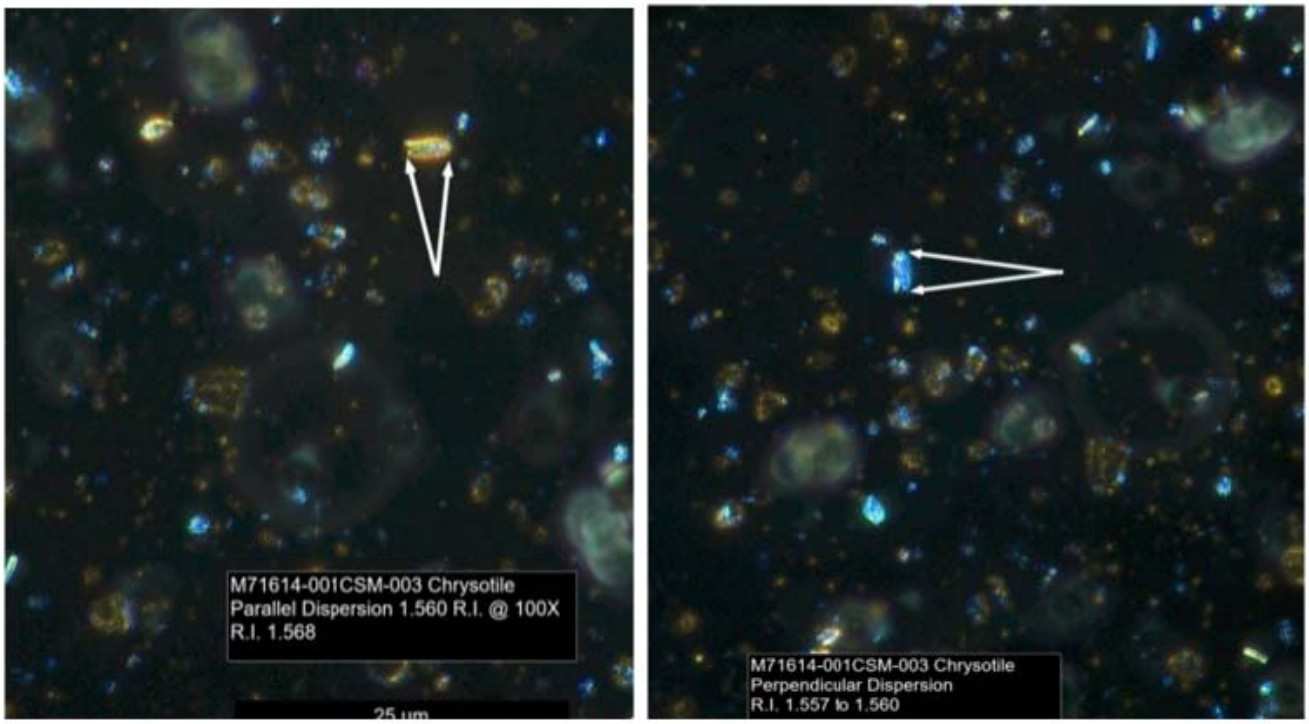



M71216-001ISO-302 Chrysotile
Parallel Dispersion 1.550 RJ. @ 100X
R.I. 1.584 to 1.568

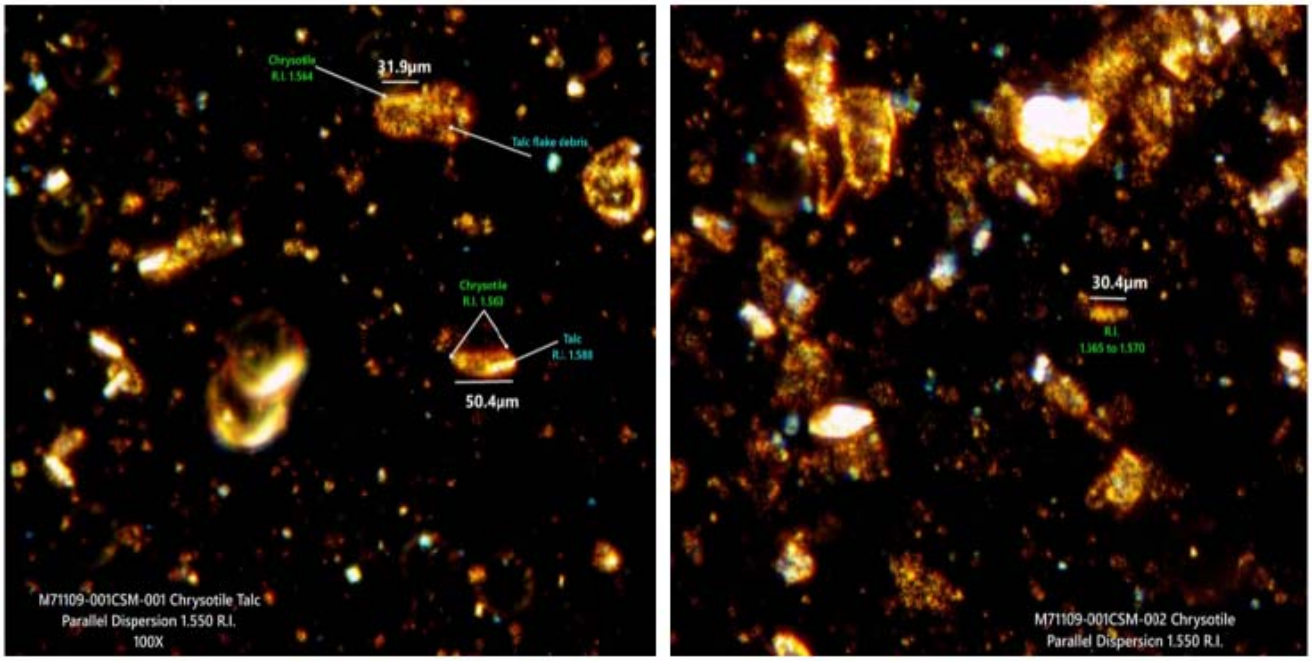

M71216-001ISO-003 Chrysotile
Perpendicular Dispersion
R.I. 1.550 to 1.553

M71214-001CSM MAS specifies λ_0 parallel 510nm, λ_0 perpendicular 650 nm T=22 nD= 1.560

Parallel **perpendicular**



MAS 71109 talc from Guangxi China nD = 1.550

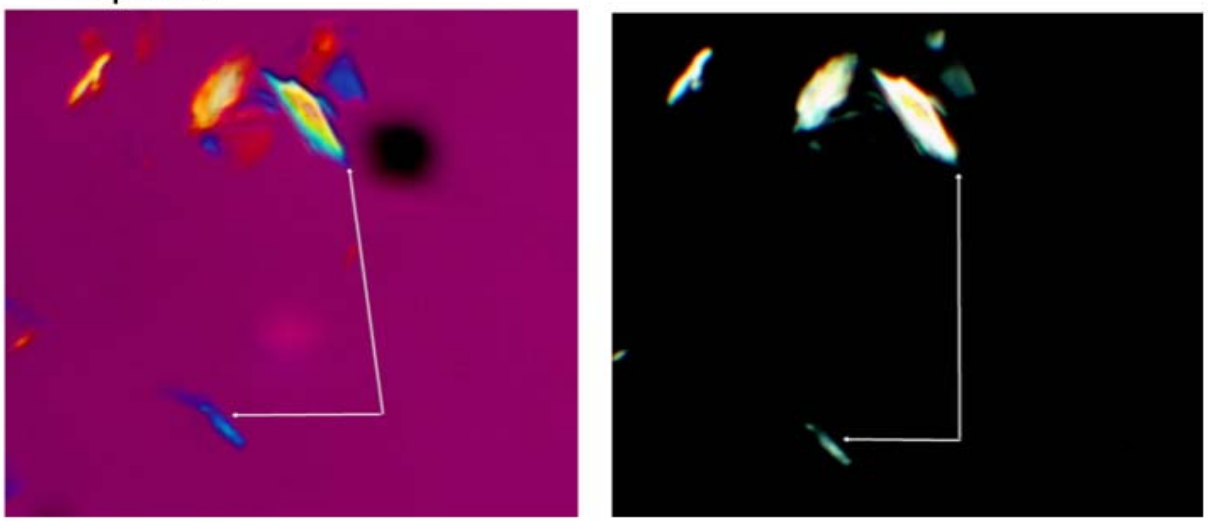


Appendix 2. Birefringence Calculations from observed retardation

a. With red I compensator, interference colors for the larger particle is second order red (950nm). It is 23um long and about 5 µm wide. Using the Interference color chart and subtracting 550 nm for the Red I compensator gives a retardation of 400nm and a birefringence of about 0.05. This is too high for chrysotile but consistent with talc. The smaller particle has interference colors blue to green (700 nm) and subtracting 550nm gives a retardation of 150 nm. It is 11 µm long so about 2µm in width. Although more difficult to pinpoint the birefringence from such a small particle, it is still on the order of 0.04.

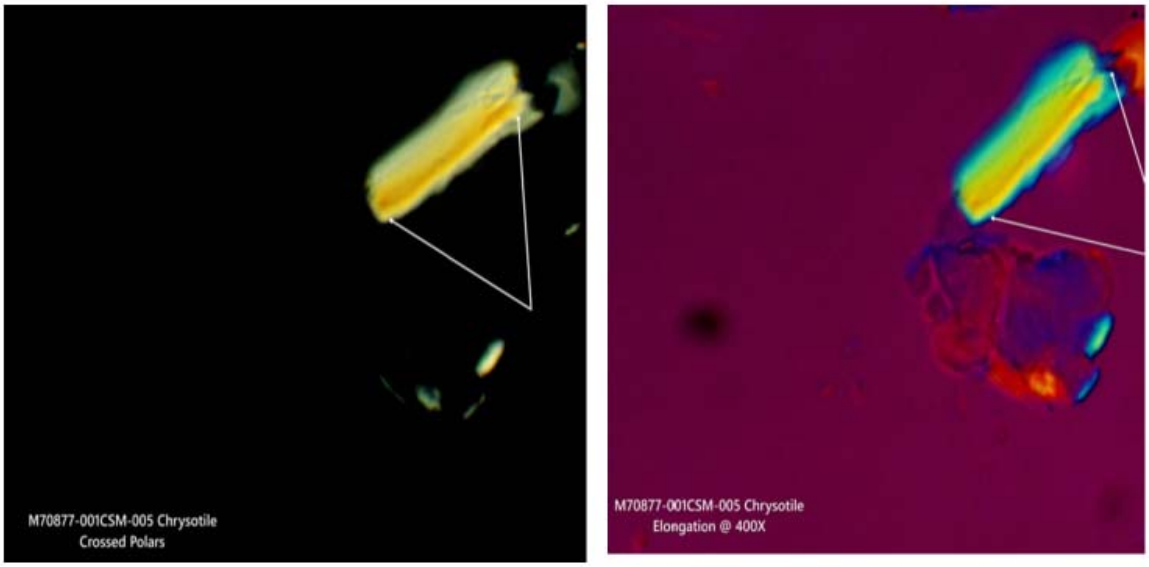
MAS70877.001CMS – 003 1.550oil

23 µ in upper right, 11 µ in lower left Red I compensator **same particles without compensator.**



b. This particle is 45.2 µm long and about 10µm in width. The figure on the left is without compensator and the figure on the right has the Red I compensator inserted. From the interference colors the retardation is about 400nm. This retardation corresponds to a birefringence of 0.040, too high for chrysotile but consistent with talc.

MAS70877 001CSM-005

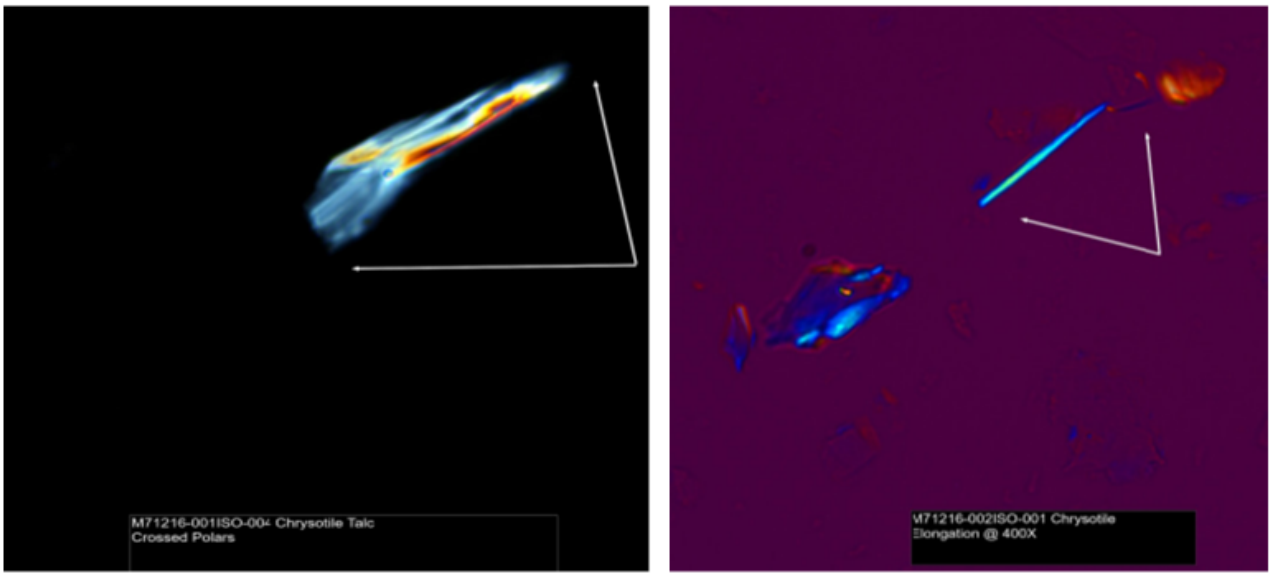


c.

Two examples from MAS M71216

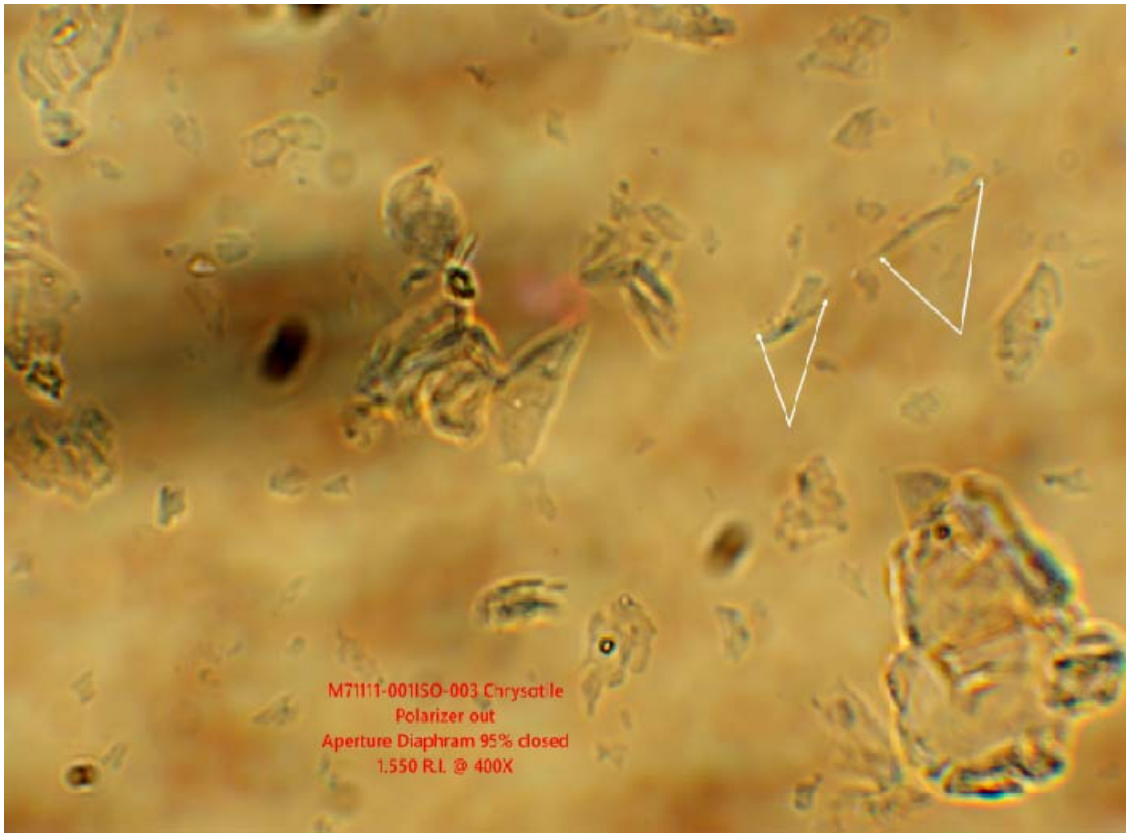
Retardation = 600nm Width ≈ 12µm birefringence ≈ 0.045

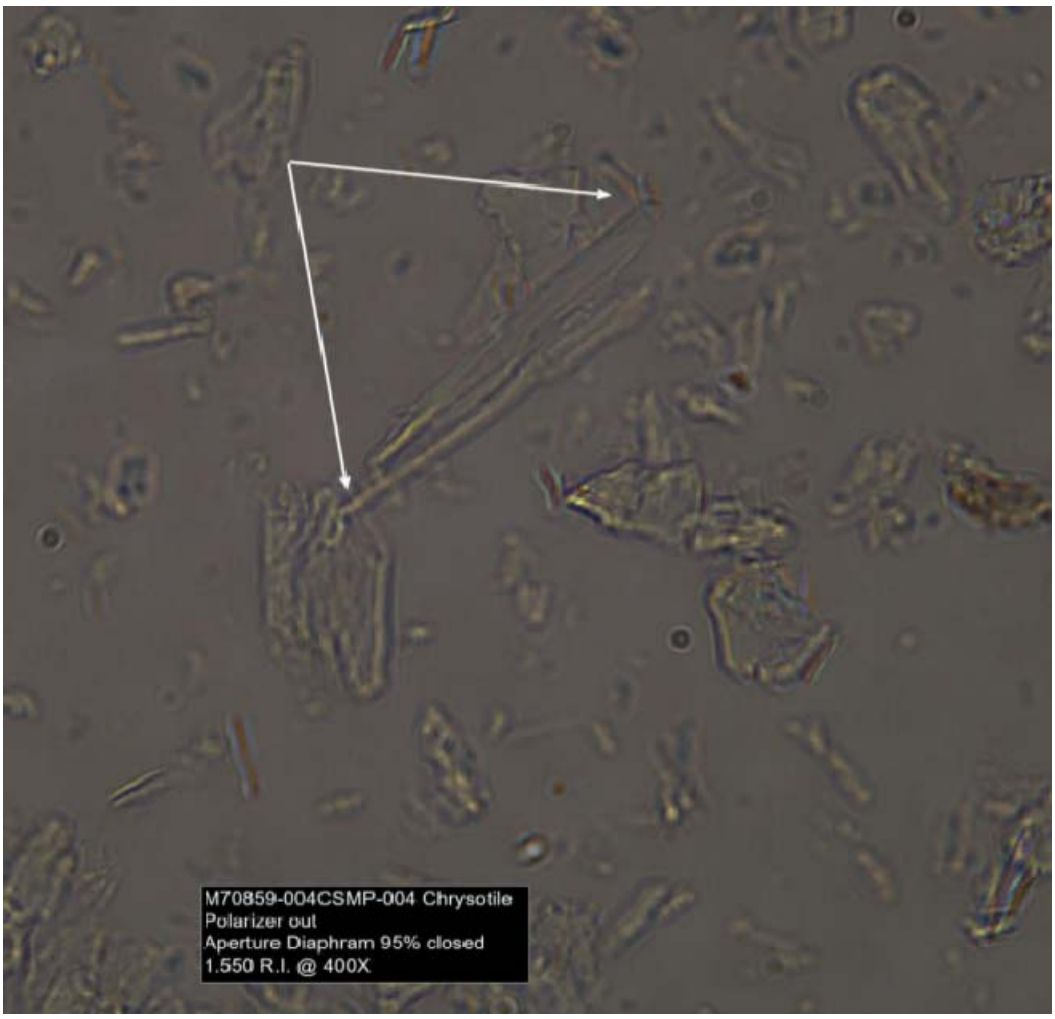
Retardation = 800-550 = 250 nm Width ≈ 2 µm; birefringence ≈ 0.050

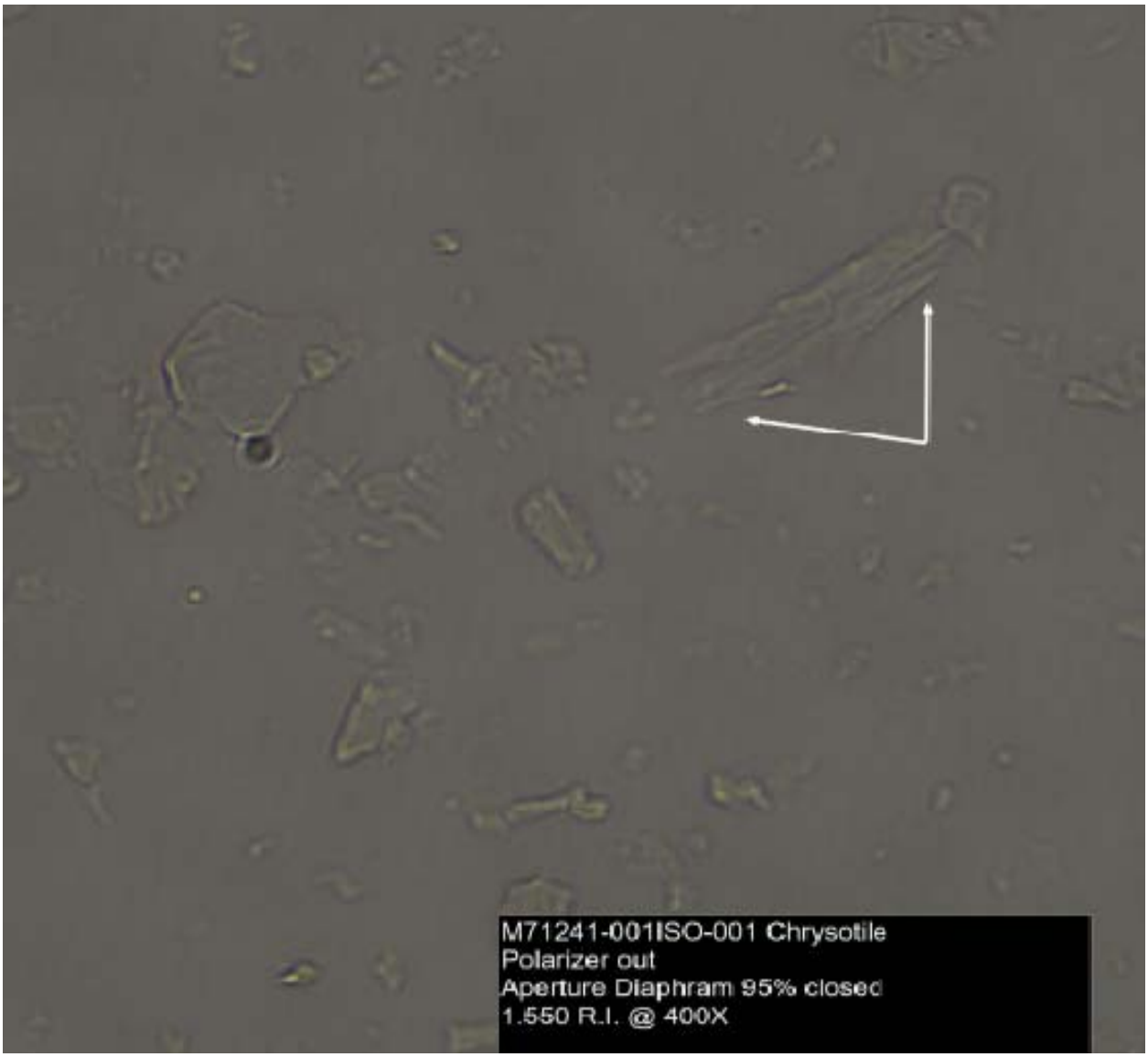


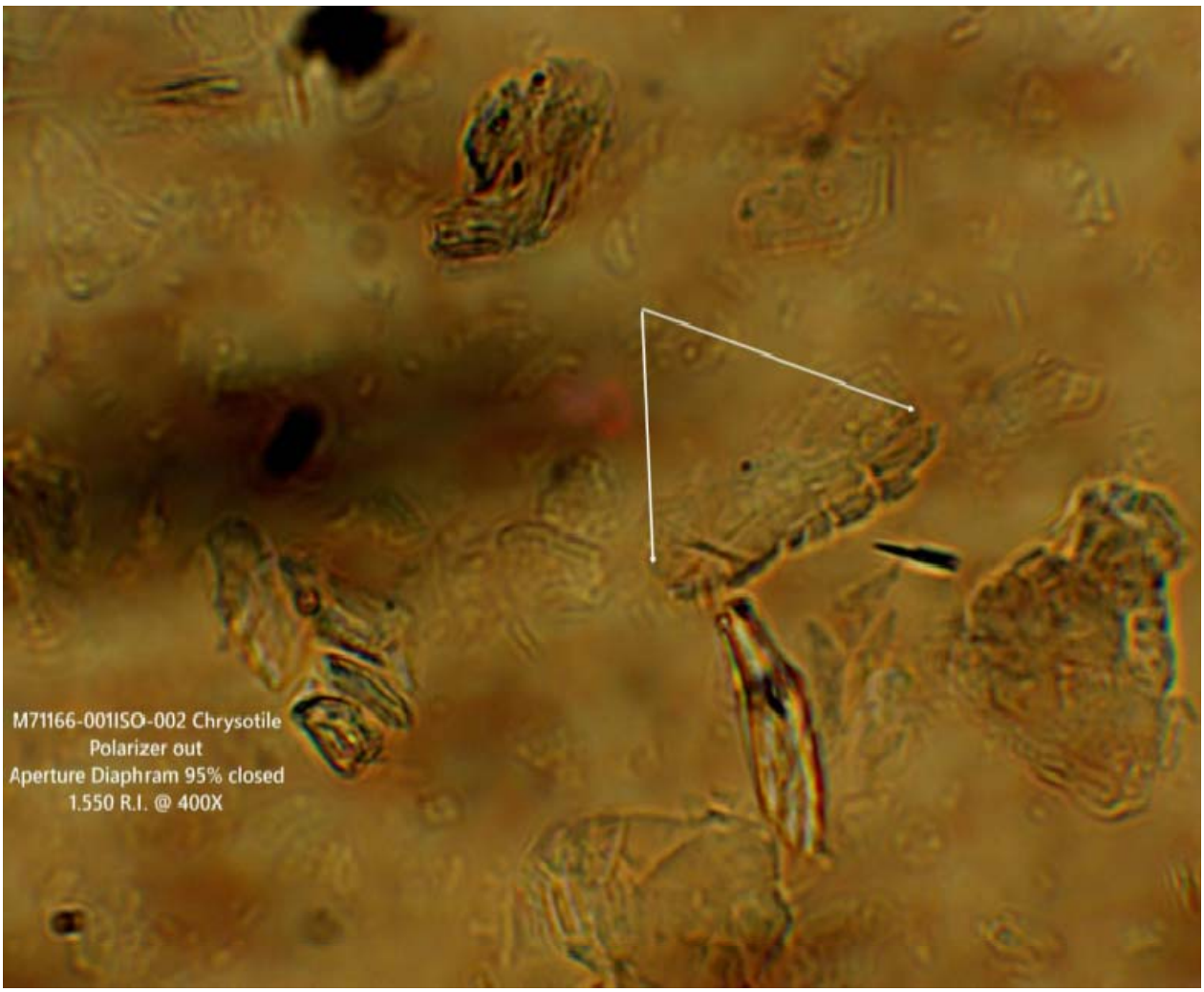
Appendix 3. Relief

The examples that follow show that the relief of the particles designated as chrysotile by the arrows have the same relief as the other particles in the photomicrograph which are talc.




M70859-004CSMP-004 Chrysotile
Polarizer out
Aperture Diaphram 95% closed
1.550 R.I. @ 400X


M71241-001ISO-001 Chrysotile
Polarizer out
Aperture Diaphram 95% closed
1.550 R.I. @ 400X


M71166-001ISO-002 Chrysotile
Polarizer out
Aperture Diaphram 95% closed
1.550 R.I. @ 400X

Appendix 4

CURRICULUM VITAE
Ann G. Wylie

1. PERSONAL INFORMATION

Ann Gilbert Wylie
Emerita Professor of Geology
University of Maryland
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E-mail: awylie@umd.edu
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Educational:

Ph.D.	1972	Columbia University, New York, New York Major: Economic Geology Minors: Mineralogy, Mining Engineering, and Petrology
B.A.	1966	Wellesley College, Wellesley, Massachusetts Major: Geology

Employment:

a. Academic:

2014 – Present	Professor Emerita, UMD
July 1 2021 – Aug 16 2021	Interim Vice President and Chief Financial Officer
Feb 2021 – June 30, 2021	Interim Senior Vice President and Provost, UMD

March 1, 2014 – June 30, 2014, Interim Vice President for Information Technology and Chief Information Officer, UMD

2012 – 2014	Special Advisor to the President for MPower, UMD
2012 – 2014	University Marshall, UMD
2011- 2012	Senior Vice President and Provost, UMD
2009- 2011	Vice President for Administrative Affairs, UMD

2008 – 2009	Interim Vice President for Administrative Affairs, UMD
2004-2006	Interim Dean of the Graduate School, UMD
2002-2008	Assistant President and Chief of Staff, UMD
2000-2002	Associate Provost, UMD
1998-2000	Acting Associate Dean, College of Computer, Mathematical and Physical Sciences, UMD
1996-1997	Undergraduate Director, Department of Geology, UMD
1992-2014	Professor, Department of Geology, UMD
1990-1994	Associate Chairman and Director of Graduate Studies, Geology Department, UMD
1989-1990	Acting Chairman, Geology Department, UMD
1986-1987	Special Assistant to the Dean for Graduate Studies and Research, UMD
1984-1986	Acting Associate Dean for Research, Graduate School, UMD
1977-1992	Associate Professor, Department of Geology, UMD
1973-1977	Assistant Professor, Department of Geology, UMD
1972-1973	Assistant Professor, Department of Agronomy, UMD
1967-1969 1970-1971	Preceptor, Geology Department, Columbia University
1966-1967	Teaching Assistant, Geology Department, Columbia University

***b. Other Positions*:**

January 1981- August 1981	Mineralogist, U.S. Bureau of Mines,
February 1984- Present	Senior Scientific Advisor, Chemical and Industrial Hygiene

2. Research, Scholarly, and Creative Activities

a. Books

i. Chapters or Articles in Books:

Gilbert, J. Ann (1967) "Units, Numbers, Symbols and Constants", Encyclopedia of Atmospheric Sciences and Astrogeology, Rhodes Fairbridge (Ed.). Reinholt Publishing Company, p. 1049-1062.

Wylie, A.G. (1981) Numerous Mineral Descriptions in Encyclopedia of Mineralogy, K. Frye (Ed.). Reinholt Publishing Company.

Steel, E. and A. Wylie (1981) "Mineralogical Characteristics of Asbestos". In Geology of Asbestos Deposits, P.H. Riordon (Ed.). Society of Mining Engineers of AIME, p. 93-100.

Candela, P.A. and Wylie, A.G. (1989) Genesis of the Ultramafite-associated Fe-Co-Cu-Zn-Ni deposits of the Sykesville District, Maryland Piedmont. Field Trip Guide T241, International Geological Congress, published by American Geophysical Union.

Invited
Veblen, D.R. and A.G. Wylie (1993) "Mineralogy of Amphiboles and 1:1 Layer Silicates" in Health Effects of Mineral Dusts, G.D. Guthrie & B.T. Mossman (Eds.). Reviews in Mineralogy, v. 28, Min. Soc. Am., p. 61-131.

Invited
Wylie, A.G. (1995) "The Analysis of Industrial Mineral Products for Crystalline Silica by Optical and Electron Microscopy: A Literature Review". In: Review Papers on Analytical Methods, Chemical Manufacturers Association.

Invited
Wylie, A.G. and P.A. Candela (1999) "Metallic Mineral Deposits - Chromite". In Geol. of Pennsylvania, Pennsylvania Geol. Survey and Pittsburgh Geol. Survey, Special Publication 1, p.588-595.

Invited
Wylie, A.G. (2017) Mineralogy of Asbestos and fibrous erionite. In *Current Cancer Research: Asbestos and Mesothelioma*, Joseph Testa Ed. Springer, Heidelberg 11-41.

Invited
Wylie, AG (2024 in press) Mineralogical Characteristics and Risk assessment of elongate mineral particles (EMPs): Asbestos, fiber and fragment in Health Risk Assessment for Asbestos and other fibrous minerals, A A Korchevskiy, ed. John Wiley and Sons

b. Edited publications

Weill P, Chatfield E, Gibbs G, Wylie A, Eds. (2018). The Monticello Conference on elongated mineral particles, Journal of Toxicology and Applied Pharmacology 367:1-186.

b. Articles in Refereed Journals

Wylie, A.G. and P.J.M. Ypma (1974) "Determination of the Optical Parameters, n and k, of Absorbing Minerals with the Microscope: Isotropic Minerals". Economic Geology 52, p. 1300-1327.

Wylie, A.G. (1979) "Fiber Length and Aspect Ratio of Some Selected Asbestos Samples". Annals of the New York Academy of Science 330, p. 640-643.

Wylie, A.G. (1979) "Optical Properties of the Fibrous Amphiboles". Annals of the New York Academy of Science 330, p. 600-605.

Zoltai, Tibor and A.G. Wylie (1979) "Definitions of Asbestos-related Mineralogical Terminology". Annals of the New York Academy of Science 330, p. 640-643.

Rohl, A.N., A.M. Langer and A.G. Wylie (1979) "Mineral Characterization of Asbestos-Containing Spray Finishes". In Asbestos Materials in Schools: A Guidance Document, Part I, EPA C0090, p. 59-64.

Wylie, A.G. and C. Huggins (1980) "Characteristics of a Potassian Winchite - Asbestos from the Allamoore Talc District, Texas". Canadian Mineralogist 18, p. 101-107.

Siegrist, H.G. and A.G. Wylie (1980) "Characterizing and Discriminating the Shape of Asbestos Particles". Environmental Research 23, p. 348-361.

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c. Book Reviews Other Articles, and Notes

Invited
Book review of Optical Mineralogy: Theory & Technique by E.G. Ehlers. In: American Scientist, Nov. /Dec. (1988).

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e. Abstracts and Professional Papers presented

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Siegrist, H.G. and A.G. Wylie (1979) "Characterizing and Discriminating the Shape of Asbestos Particles", GSA Annual Meeting San Diego, California.

Invited

Wylie, A.G. and P. Schweitzer (1980) "The Effects of Grinding on the Shape of Wollastonite Particles". Symposium on Electron Microscopy and X-ray Applications to Environmental and Occupational Health Analysis, Penn State.

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Bodies in the Eastern Piedmont of Maryland". Geol. Soc. of America Northeastern Section, March (1985).

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Linder, D.E. and Wylie, A.G. (1988) "Zeolites from the Paleozoic Metavolcanic James Run Formation, Piedmont Province, MD" Southeast Geol. Soc. Amer.

Invited
Wylie, A.G. "Discriminating Amphibole Cleavage Fragments from Asbestos: Rationale and Methodology. Abstracts of Communication. VII International Pneumoconiosis Conference, Aug. 23-26, 1988. Pittsburgh, NIOSH-ILD-BOM-MSHA-OSHA, p. 124.

Invited
Wylie, A.G. (1989) "Distinguishing Tremolite-Asbestos from Tremolite Cleavage Fragments on a Light Optical and Morphological Basis", VII International Pneumoconiosis Conference Proceeding of Workshop: Hazard Recognition of Mineral Dust. Pittsburgh, NIOSH-ILD-BOM-MSHA-OSHA.

Invited
Wylie, A.G., (1989) Fiber Mineralogy and Identification. Society of Mining Engineers Annual meeting

Wylie, A.G., Linder, D. and Candela, P. (1990) "Sedimentary Features of Appalachian Serpentinites". Geol. Soc. of Amer. National Meeting, Nov. (1990), p. A230.

Invited
Skinner, C. and Wylie, A. (1990) "Fibrous Tremolites". Bloss Symposium, VPI, Blacksburg, Virginia.

Invited
Wylie, A.G. (1992) The Analysis of Industrial Mineral Products for Crystalline Silica by Optical and Electron Microscopy. The Measurement of Crystalline Silica International Symposium, August (1992).

Wylie, A.G. (1993) The Fractal Distribution of the Mass of Asbestos Fiber and its Application to the Analysis of Industrial Minerals. Geological Society of America Annual Meeting, Boston.

Verkouteren, J.R. and Wylie, A.G. (1994) “Anthophyllite, Tremolite, and Actinolite Asbestos: Reference Materials and Optical Properties” Inter/Micro 94, Chicago.

Verkouteren, J.R., Wylie, A.G., Steel, E.B., Lim, M.S. (1995) "Analysis of the Tremolite-Actinolite Series using High Precision Refractive Index Measurements". Microbeam Analysis.

Invited
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Wylie, A.G. (1997) "The Habit of Asbestiform Amphiboles: Implications for the Analysis of Bulk Samples” 1997 Boulder Conference: Advances in Environmental Measurement Method for Asbestos. University of Colorado, Boulder, July 13-17 (1997).

Verkouteren, J.R. and A. G. Wylie (2001) “Microdiffraction Analysis of Fibrous Talc: Asbestos in Crayons”. 2001 Denver X-ray Conference, Steamboat Springs, Colorado, USA, August 2, 2001.

Piccoli, P.M., DeHarde, A., Wylie, A.G. (2001) “Recycling coal Combustion Byproducts: a Laboratory Study to Evaluate Grout Formulations for Use in the Kempton Mine Complex, Western Maryland. Geological Society of America, Abstracts with Programs.

Verkouteren, J.R. and A.G. Wylie (2001) “Identification of Tremolite-Actinolite Asbestos”. 2001 Asbestos Health Effects Conference, May 24-25, 2001, Oakland, CA.

Verkouteren, J.R., A. G. Wylie, E. Windsor, J. Courny, R. Perkins, T. Ennis (2002) “Powder X-Ray Diffraction for Asbestos Analysis”. International Centre for Diffraction Data. Annual Meeting of Members, ICDD Headquarters, Newtown Square, PA, March 20, (2002).

Greenwood, W. and A.G. Wylie (2002) “The Optical Properties and Chemical Composition of Fibrous Talc”. ASTM Johnson Conference, July 21-25, Johnson, Vermont.

Verkouteren, J.R., and A.G. Wylie (2002) “A PLM Method for Quantitative Analysis of

Amphibole Asbestos in Bulk Materials at 0.01 wt. %". ASTM Johnson Conference, July 21-25, Johnson, Vermont.

Verkouteren, J.R. and A.G. Wylie (2002) "Optical Characteristics and Mineralogy of Environmental Amphibole Asbestos", ASTM Johnson Conference, July 21-25, Johnson, Vermont.

Verkouteren, JR and A G Wylie "Micro-diffraction Analysis of Fibrous Talc: Asbestos in Crayons. Denver x-ray conference.

Crummett, C.D., Candela, P.A., Wylie, A. G., and Earnest, D.J. (2004) "Examination of the Thermal Transformation of Chrysotile by Using Dispersion Staining and Conventional X-ray Diffraction Techniques". AGU Fall Meeting, V41C-1405.

Earnest, D. J., Candela, P.A., Wylie, A. G., Crummett, C. D, Frank, M. (2004) "Synchrotron Radiation Study of the Kinetics of Dehydration of Chrysotile Fiber". AGU Fall Meeting, V23C-06.

Frank, MR, Candela, PA, Earnest, DJ and Wylie, AG, Wilmot, M, Maglio SJ (2005) Experimental Study of the Thermal Decomposition of Lizardite up to 973 K, GSA Annual Meeting

Kerrigan, RJ, Candela, PA, Piccoli, PM, and Wylie, AG, (2007), Growth of Fibrous Talc and Anthophyllite in the Hydrothermal Diamond Anvil Cell (HDAC), American Geophysical Union Fall Meeting, December 10-14, 2007, San Francisco.

Taylor, ES, Lower, SK, Wylie, AG, and Mossman, BT: The strength of disease: molecular bonds between asbestos and human cells, EOS Trans. AGU, *89*(53): B53B-0479, 2008.

Schwartz, C.W., Wylie, A.G., Davis, A.P., and James, B.R., (2009), Column Expansion Testing of Chromium tailings Subgrade Fills, International Foundation Congress and Equipment Expo, March 15019, Orlando, FL, 8 pages.

Invited
Wylie, A.G. (2010) Mineralogical Characteristics of Asbestos. GSA meeting, Northeastern/Southeastern sections, Baltimore.

Taylor E, Mossman BT, Wylie AG, Lower SK. (2010) Molecular Methods for the induction of Mesothelioma by Asbestos. GSA meeting Northeastern/Southeastern sections. Baltimore.

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Wylie, A. G. (2013) A Review: Mineralogy and dimensional characteristics of amphiboles from the vermiculite deposit, Rainy Creek Complex, Libby, Montana. GSA meeting Northeastern Section, Bretton Woods, New Hampshire

Invited
Mossman, B.T., Sonali, H, Taylor, E, Lower, S, Dragon, J, bond, J, Wylie, A, and Shukla, A (2013) New Data on How Asbestos Fibers Interact with Cells to Trigger Extracellular Signal-Regulated Protein Kinase, i.e., ERK, Pathways Critical to Toxicity and Disease, 10th International Meeting on fibre/Particle Toxicology, June 407, Dusseldorf, Germany

Segrave, A, Wylie A, and Korchevskiy (2019) Amphibole dimensions and predictive model for potency. ASTM Beard Conference. Denver April 4

Invited
Wylie, A (2019) What makes an amphibole asbestos? History and status of regulatory issues dealing with asbestos. Mineralogical Society of America 100th Anniversary Symposium. Washington DC, June 2019, http://www.minsocam.org/MSA/Centennial/MSA_Centennial_Symposium.html#S1

Invited
Wylie, A (2019) A metrological look at natural occurrences of amphibole. Association of Economic and Environmental Geologists annual meeting. Asheville NC Sept 19

Invited
Wylie, A and Korchevskiy A (2020) Fibers vs mineral Fragments: Mineralogical and Toxicological aspects. Asbestos 2020 Conference, British Occupational Health Society London Nov 18 2020

Wylie, A (2022) Dimensional parameters and cancer determination of relevant variables. The Monticello Conference, Charlottesville VA April 2022.

Korchevskiy, A and Wylie A (2024) Asbestos terminology: Mineralogical, toxicological and analytical considerations. ASTM Beard Conference, Philadelphia PA April 2024.

f. Guides for Field Trips:

Wylie, A. and P. Candela (1987) "The Geology of the Maryland Piedmont". 3-day Trip and Guide Book. Department of Geology Annual Trip, October 1987.

Candela, P. and A. Wylie (1988) "The Ultramafite-associated Cu-Fe-Co-Ni-Zn Deposits of the Sykesville District, Maryland Piedmont". Goldschmidt Conference Field Trip, May, 1988.

Candela, P. and Wylie, A. (1989) "Fe-Cu-Co-Ni-Zn deposits of Sykesville, Md." International Geological Congress,T241 July 1989. John Wiley and sons

Candela, P. and A. Wylie (1990) "The Ultramafite-associated Cu-Fe-Co-Ni-Zn Deposits of the Sykesville District, Maryland Piedmont". Goldschmidt Conference Field Trip, May, 1990.

Wylie, AG. (2018) Geology of the Catoctin Mountains, MD. June 9, 2018. Geological Society of Washington Spring Field Trip.

Wylie, AG (2022) Geology of the Catoctin Mountains, MD, Nov 6, 2022, Department of Geology University of Maryland College Park

g. Research Grants

Asbestos", U.S. Bureau of Mines, $84,200. April 1979-April 1981.

Principal Investigator, "Dispersion Staining in Optical Mineralogy", Undergraduate Fund for Improvement of Instruction, University of Maryland, $700. 1982.

Principal Investigator, "Quality Control in the Analysis of Asbestos by PLM", $10,000. Sept. 1985-Sept. 1986. Occupational Medical Center.

Principal Investigator "Mineralogy of the Sand Fraction of Aquifer in Northwestern Washington". United States Geological Survey, $2,450. June-October 1986.

Univ. of Maryland General Research Board Semester Research Award, $1,500. 1987.

Mineralogy of Waste Product of Sand and Gravel Processing". Aggregate Industries, $12,000. 1987-1988.

Characterization and Quantification of Fibrous Tremolite in Tremolitic Talc. Southern Talc Company, $17,000. 1989-1990.

Principal Investigator, "Mineralogical Characteristics of Fibrous Talc". R.T. Vanderbilt Company, $23,500. September 1992-December 1997.

Project Director, "Fellowship for the Study of Industrial Talc". R.T. Vanderbilt Company, $33,500. January 1, 1993-December 31, 1997.

Co-Project Director, (with C Schwartz) “Research and Laboratory Testing of Chromium Processing Waste at Dundalk Marine Terminal”, Maryland Department of Transportation, $100,000. December 1996-December 1997.

Co-Project Director (with K Prestegaard and A Amde) “Characterization of Coal Combustion Products and Derived Grout Materials,” Nuclear Power Plant Research Program, Maryland Department of the Environment, $10,000, 1998.

Co-Project Director (with K Prestegaard and A Amde) “Characterization of Coal Combustion Products and Derived Grout Materials, Nuclear Power Plant Research Program, Maryland Department of the Environment, $60,000, 1999

Co-Project Director, (with K Prestegaard and A Amde)"Characterization of Coal-Combustion Products and Derived Grout Material". Power Plant Research Program, Maryland Department of Natural Resources, $40,000, 2000.

Co-Project Director, (with K Prestegaard and A Amde)"Characterization of Coal-Combustion products and Derived Grout Material (supplement)□□□ Power Plant Research Program, Maryland Department of Natural Resources, $60,000, 2000.

Co-Project Director, (with K Prestegaard and A Amde) "A study of the Mineralogical Transformations in Fly-Ash Based Grouts. Maryland Department of Natural Resources, Power Plant Research Program, $30,000, 2000-2001

Co-Project Director (with P Candela) "A study of the thermal transformation of chrysotile", Ford, GM and Chrysler, $610,000, 2004-2006

h. Fellowship, Prizes and Awards

Seven College Conference of Women's Colleges Scholarship to Wellesley College, 1962-1966.

Wellesley College Scholar, 1966.
Wellesley College B.A., *cum laude*

Faculty Fellowship, Columbia University, 1969-70, 1971-72.

Citation from Governor, State of Maryland, for recognition of assistance in implementation of Title IX in Maryland, 1983.

Butler Prize, Geological Society of Washington, 1989. Given for the best paper read before the Society, 1989.

Distinguished Scholar-Teacher 1994 UMCP.

Fellow Geological Society of America 1990

Honorary Membership in Zeta Nu chapter of Eta Sigma Phi 2011

Outstanding Woman of the Year, President's Commission on Women's Issues, 2012

President's Medal, University of Maryland, 2014

Induction in Phi Kappa Phi 2021

3. Teaching, Mentoring, and Advising

a. Courses taught

Course	Approximate Average Enrollment
Physical Geology	150
Economic Geology	10
Optical Mineralogy	6-10

Ore Microscopy	3
Senior Thesis Research	10
Advanced Topics in Economic Geology	14
Geology of Maryland	6
Geology and Public Policy	15
Environmental Geology	60
X-ray diffraction	8

b. Advising: Research Direction

i. Undergraduate Thesis (beginning 1980) Major Advisor:

1980 [16]Ed. Jacobsen "Coal Geology of Garrett County, Maryland"

1982 Sharron O'Donnell "Coal Geology of Southwestern Kentucky
Eric Windsor "Shape Characterization of Amphiboles"
Morris Levin "Characterization of Part of the Sykesville Magnetite District by a Magnetometer"
Lyle Griffith "The Use of a Magnetometer in Characterizing the Beasman Prospect, Sykesville, MD."
[17]John Varndell "Heavy Element and Particle Size Relationships in a Sludge Disposal Site, Baltimore, Maryland"
Joe Segretti "Relationship between cytotoxicity and coating of chrysotile fibers"
Mark Beal, A Geologic Evaluation of a Placer Gold Deposit in Southern Fauquier Co., Virginia

1983 Keith Mason "A Preliminary Evaluation of Copper and Cobalt in Conjunction with Iron Mining in the Beasman Prospect of Sykesville, Md."
Michael D. Jones "Chromium in the Soils and Streambeds above the Hunting Hill Serpentinite Body, Montgomery County, Md."
Theresa Baker "Crack Growth in Quartz: The Effects of Chemical Environments"
Mark Hevey "Gas Production and Faulting in Gas Field, Kansas"

1984 Brian Hart "A Potential Field Study of the Magnetite Bearing Deposits of the Central Portion of the Sykesville Mining District"
Katherine Heller "A Reconnaissance Study of the Origin of Small Talc and Serpentine Bodies in the Wissahickon Formation within the Maryland Piedmont"

1987 Dan Linder "Comparison of the James Run with the Sykesville and Morgan Run Formation"
Bethany Baker "Observation on the Geology of Montgomery County from geomagnetic, aeroradioactivity and gravity surveys"
Valerie Gray "Reconnaissance Study on the Source of Gamma Radiation

[16]Winner of the AAPG National Undergraduate Research Award
[17]2nd Place Winner of the AAPG National Undergraduate Research Award

Fluctuation in Eastern Montgomery County"

1988 Tom Davis "Comparative Geothermometry by Using Garnet-Biotite and Fe-Ti Oxides in the Loch Raven Schist

1991 Dan Galasso "Geochemical Prospecting of Heavy Minerals to Determine if a Marker Exists for the Sykesville District of Carroll County, MD"

1994 David Berry "Analysis of Trace Quantities of Amphibole Asbestos Based on the Fractal Model for Mass Distribution"

1995 Bob Schultz "Determination of Asbestos in a Matrix Through Employment of the Fractal Model for Mass Distribution"
Allan Jackson-Gewirtz "A Comparison of Methods of Analysis of Powdered Samples"
Roberta Winters "Biological Effect of Fiber Size and Mineralogy: The Case of Talc Fibers in Hamster Tracheal Epithelial (HTE) and Rat Macrophage Cells (RMC)"
Mi Lim "Anomalous Optical Properties of Tremolite-Actinolite Fibers"

1996 Tom Biolsi "Effects of absorption and thickness in measuring the index of refraction of blue glass and riebeckite and its application to crocidolite"
Katherine White "X-ray diffraction and optical analysis of picrolite from the State Line Quarry, PA"
Christine Rosenfeld, "Characterization of the Chemistry of the Zeolites Erionite and Mordenite as a Function of Morphology: An SEM/EDS study"

1997 Matt McMillan "Lattice dimensions *vs.* chemical composition and optical properties of tremolite"

1999 Russell Meyer "Lattice Dimensions, chemical composition and optical properties of crocidolite"

ii. Master of Science Degree Awarded

1985 John Ossi, M.S., "A New Petrographic Method for Interpreting Coal-Forming Environments of Deposition"

1988 Robert Virta, M.S., "An Evaluation of the Adequacy of Morphological Data for Determining the Carcinogenicity of Minerals"

1990 Dan Linder, M.S., "The Mineralogy and Origin of the State Line Talc Deposit, Lancaster Co., Pennsylvania"

1991 Tim Rose, M.S., "Petrology and Chemical Variation of Peraluminous Granitic Rocks from the Northern Lobe of the Phillips Pluton, Maine"

1996 Jiang Feng, M.S., "Evidence for compositional variation in phyllite from Carroll

and Frederick Counties, MD"

1988 William Greenwood, M.S. “Mineralogical Characteristics of Fibrous Talc”

Diane Hanley, M.S., "Overland flow evaluation of lava flow platform"

1999 Mark Watson, M.S., “Effects of intergrowths on the Physical Characteristics of fibrous Anthophyllite”

2001 Amina DeHarde, M.S., “Characterization of Grouts made from Coal Combustion By-Products: Mineralogy and Physical Properties”

2005 Courtney Crummett, M.S. (co-chair) "Examination of the Thermal decomposition of Chrysotile”

iii. Ph.D.

1991 James Crowley, Ph.D., "Geochemical Study of Playa Efflorescent Salt Crusts and Associated Brines by Using Spectral Reflectance, X-ray Diffraction and Brine Chemical Data"

1999 Martitia Tuttle, Ph.D., "Late Holocene Earthquakes and their Implications for Earthquake Potential of the New Madrid Seismic Zone, Central United States"

4. SERVICE

a. Professional

i. Offices and Committee Membership Held in Professional Organizations

Geological Society of America (Fellow)
Mineralogical Association of Canada
Geological Society of Washington
American Association for the Advancement of Science
American Geophysical Union
Geological Society of America Campus representative (1985-2000)
Chairman, Sigma Xi Graduate Student Research Award Selection Committee, UMCP (1986, 1987)
Mineralogical Society of America: Tellers committee, 1989-1991.
Representative to American Geological Institute, K-12 Education Committee, 1991
Field Trip Chairman, Geological Society of Washington, 1990.
Delegate to AAPG - Geological Society of Washington 1995-96.
International Mineralogical Association Chair, Committee on Asbestos nomenclature 2019-2022

ii. Reviewing Activities for Journals and Agencies

American Mineralogist
Canadian Mineralogist
Science
Environmental Research
U.S. Bureau of Mines
European Journal of Mineralogy
Periodico di Mineralogia
Environmental Protection Agency
U.S. Geological Survey
Economic Geology
Society of Mining Engineers
American Industrial Hygiene Journal
Critical Reviews in Toxicology
Scientific Reports
National Institute for Occupational Safety and Health
Risk Analysis

iii. Other Professional Activities

Co-Chairman, New York Academy of Sciences, Workshop #1. Significance of Aspect Ratio in Regulation of Asbestos Fiber Exposure, Conference on the Scientific Basis for the Public Control of Environmental Health Hazards, New York (1978).
Invited Chairman and Organizer of "Asbestiform Minerals Symposium", AIME Annual Meeting (1979) Tucson, Arizona.
Appointed by the U.S. Secretary of Education to the Task Force on Asbestos in the Schools (1980-1984).
Session Chairman, EPA Conference on Monitoring and Evaluation of Airborne Asbestos Levels Following Abatement, March, 1984.
Appointed reference analyst for U.S. Navy Asbestos Analysis Quality Assurance Program (administered by Research Triangle Institute) 1984-1990.
Session Chairman, Economic Geology III, Geol. Soc. of Amer. National Meeting, November 1985.

Member, ASTM Task Group for writing Standard Methods of Analyses of Asbestos by TEM, SEM, Phase Contrast Optical Microscopy and Polarized Light Microscopy. 1985-1990. Author of Polarized Light Microscopy Method (grey sheets).
Expert witness, Occupational Safety and Health Administration hearing on asbestos regulation, 1985, 1990.
Invited participant, Penn. Geol. Survey Conference on Mapping in the Piedmont, 1987.
Expert panel member, EPA, Superfund Bulk Asbestos Method, 1990-1991.
Member IARC Work Group for Talc, Carbon Black, and Titanium Dioxide, Lyon France 2006.
Wellesley College, Class of 1966 Class Officer 1981-86, 2006-11; Annual giving committee 2012-2016
Member, Peer Review Panel, NIOSH, Roadmap for Scientific Research on Asbestos and Other Mineral Fibers, 2007
Testimony, US House Senate, Committee on Environment and Public Work June 12, 2007 and follow-up letter, June 16, 2007
Member, Scientific Advisory Board, National Stone, Sand and Gravel Association 2011-present
Member, Frederick Regional Higher Education Advisory Board 2013-2015
Member, Frederick Center for Research and Education in Science and Technology (CREST) Governing Board 2015-2018
Member Planning Committee for NIOSH EMP workshop on Terminology and Characterization, Paul Middendorf Chair 2016 (rescheduled by CDC to 2017).
Invited participant and member of the Planning Committee, National Academies Workshop on elongated Mineral Particles, May 15-16 2017. (Rescheduled to January 2018: cancelled by NIOSH in January)
Co-chair NSSGS/Society of Toxicology Monticello Conference on EMPS, October 2017, Charlottesville, VA
Guest editor. Special issue of Toxicology and Applied Pharmacology: The Monticello Conference.
Invited speaker and session co-moderator, JIFSAN workshop. Asbestos in talc. Nov 2018
Steering committee and session co-chair: Dimensions and Mesothelioma. The Monticello Conference II on Elongated Mineral Particles and Cancer. April 2022, Charlottesville VA

c. Selected University of Maryland Service

Chairman, Institutional Review Board (IRB) 1984-1986
Supervisory responsibility for Animal Care and Use Committee and actions (1984-1986)
Chair, General Research Board 1984-1986
Chair, Creative and Performing Arts Board 1984-1986
Member Review Committee for Dean of the College of Computer Mathematical and Physical Sciences 1990
Member, Review Committee for Chair of Department of Economics 1998
Chair, Earth System Science Director Search Committee 1998
Chair, Limited Enrollment Committee, 2000-2002
Chair, Campus Assessment Working Group, 2000-2002
Chair, Search Committee, Vice President for Research 2002
Chair, Search Committee, Vice President for Administration and Finance, 2004
Chair, UMCP Graduate Council, 2004-2006
UMCP Strategic Planning Steering Committee, Graduate Education Chair, 2008

Chair, UMCP Finance Committee, 2008-2011
Chair, UMCP Sustainability Council 2009-2011
Chair, Student Fee Review Committee 2008-2011
Chair, UMCP Facilities Council, 2011-2012
MPowering the State, UMB-UMCP Steering committee 2011-2013
Carey School of Law Dean Search committee 2013-2014
Facilitator, Leadership Fellows Program, UMCP Advance. 2013-2014
College of Computer, Mathematical and Natural Sciences, University of Maryland, Board of Visitors, 2013-2018
Member. UM Investigation Committee for scholarly misconduct case. 2015
Chair, Investigation Committee to review UM Maryland Industrial Partnership grant to Fifth Quarter Fresh and School of Public Health. 2016
Chair, Transition Committee, President Designate Professor Darryll Pines, University of Maryland, 2020
Chair, Task Force on Geoscience, College of Computer, Math and Natural Sciences, 2020
Chair, Climate Working Group, University of Maryland, 2023

Appendix 5 – List of MAS Reports Identifying "Chrysotile" in Johnson & Johnson Talcum Powder Products

Date	MAS Project Number(s)
2/24/2020	M70484
3/6/2020	M66515 & M66516
3/18/2020	M71095
3/20/2020	M70877
4/6/2020	M71046
5/14/2020	M71095 Rev 1
9/16/2020	M71109-M71111
9/17/2020	M71166
9/23/2020	M71095 Rev 2
9/29/2020	M71166 Sup 1
12/8/2020	M71166 Sup 2
1/25/2021	M71211
2/9/2021	M71241
3/23/2021	M65329-013; M66507-001; M66508-001; M66509-001; M66513-001; M67420-001; M67420-002; M67420-004; M67420-005
4/13/2021	M71216
5/25/2021	M71228
6/4/2021	M70859
8/20/2021	M70877
3/11/2022	M71262
2/28/2023	M71614
10/19/2023	M71643
11/28/2023	M71730
2/15/2024	M71740

Appendix 6 – Reference List

In addition to the documents listed on my *curriculum vitae*, which is attached as Appendix 4, I have also cited to the below references as part of this report:

Bloss, F. Donald, An introduction to the Methods of Optical Crystallography. Holt, Rinehart and Winston, New York, 1960.

Bloss, F. Donald, Optical Crystallography. MSA Monograph Series 5. Mineralogical Society of America, 1999.

Cargille, Refractive Index Liquids, *available at* https://www.cargille.com/refractive-index-liquids.

Deer, WA, Howie RA and Zussman J, Rock Forming Minerals Volume 3B second edition: Layered Silicates excluding micas and clay minerals The Geological Society London, 2009.

ISO 22262-1:2012(E), Air Quality – Bulk Materials – Part 1: Sampling and Qualitative Determination of Asbestos in Commercial Bulk Materials, 2012.

McCrone, Walter, The Asbestos Particle Atlas, Ann Arbor Science, Ann Arbor Michigan, 1980.

McCrone, Walter. Undated Determinative Tables and Charts supplied with the McCrone Dispersion
Staining Objectives. Published by Walter C McCrone Associate, Chicago Illinois as the Particle Analyst's Handbook

Mumpton, FA and Thompson CS, Mineralogy and origin of the Coalinga asbestos deposit. In Clays and Clay minerals 23:131-143. 1975

Perkins RL and Harvey BW Test Method: Method for the determination of asbestos in bulk building materials. USEPA/600/R-93/116, 1993.

Shu-Chun, Su., A rapid and accurate procedure for the determination of refractive indices of regulated asbestos minerals, American Mineralogist 88:179-182, 2003.

Exhibit 62

THE MICROSCOPE • Vol. 69:2, pp 51–69, 2022

The Dispersion Staining Technique and Its Application to Measuring Refractive Indices of Non-opaque Materials, with Emphasis on Asbestos Analysis

Shu-Chun Su, Ph.D.
Technical Expert, National Voluntary Laboratory Accreditation Program
National Institute of Standards and Technology[1]

ABSTRACT

Refractive index (RI) is the most important optical property of non-opaque materials. It is the leading diagnostic optical property of non-opaque materials, especially asbestos minerals. Dispersion staining (DS) has been proven to be the most effective technique with desirable accuracy for the measurement of asbestos minerals' RI using the immersion method by polarized light microscopy (PLM). This paper presents a practical procedure for this measurement. To facilitate the analysis, two comprehensive suites of pre-calculated look-up tables for the conversion of the observed matching wavelength to RI were constructed for the two major types of RI liquids: Cargille Laboratories (Cargille) and Delaware Research Institute of Microscopy and Material Characterization LLC (DRIMMC), respectively, covering the range of RI liquids suitable for analyzing the six regulated asbestos minerals. RI liquid calibration in the absence of an Abbe refractometer is discussed. An alternative solution using Cargille optical glass standards is proposed, and two comprehensive suites of pre-calculated look-up tables for both Cargille and DRIMMC liquids are included, covering the range of RI liquids routinely used in the analysis of the six regulated asbestos minerals.

Keywords: dispersion staining, central stop, annular stop, refractive index, immersion method, polarized light microscopy, refractive index liquid, refractive index liquid calibration, Cargille, DRIMMC, asbestos, non-opaque material, amphibole, amosite, grunerite, crocidolite, riebeckite, tremolite, actinolite, anthophyllite, bulk asbestos sample, conversion table

Scan this QR code to download the four conversion tables (PDF files) for Cargille and DRIMMC RI liquids used in asbestos RI measurement and liquid calibration on www.mccroneinstitute.org[2].

INTRODUCTION

The Asbestos Hazard Emergency Response Act (AHERA), United States Code 15 (1) requires local educational agencies to inspect their school buildings for asbestos-containing building materials, prepare asbestos management plans, and perform asbestos response actions to prevent or reduce asbestos hazards. AHERA defines six asbestiform minerals, i.e., chrysotile, amosite (grunerite), crocidolite (riebeckite), tremolite, actinolite, and anthophyllite to be regulated hazardous asbestos minerals. AHERA also mandates the use of U.S. Environmental Protection Agency (EPA) protocol (2) for the analysis of asbestos content in bulk insulation materials. The analysis uses polarized light microscopy (PLM) to identify and quantify the asbestos minerals in bulk samples, requiring the measurement of six optical properties: color, pleochroism, refractive index (RI), birefringence, extinction, and sign of elongation.

[1]100 Bureau Drive, Gaithersburg, MD 20899; shuchunsu@gmail.com
[2]https://www.mccroneinstitute.org/v/1624/The-Microscope-Volume-69-Second-Quarter-2022

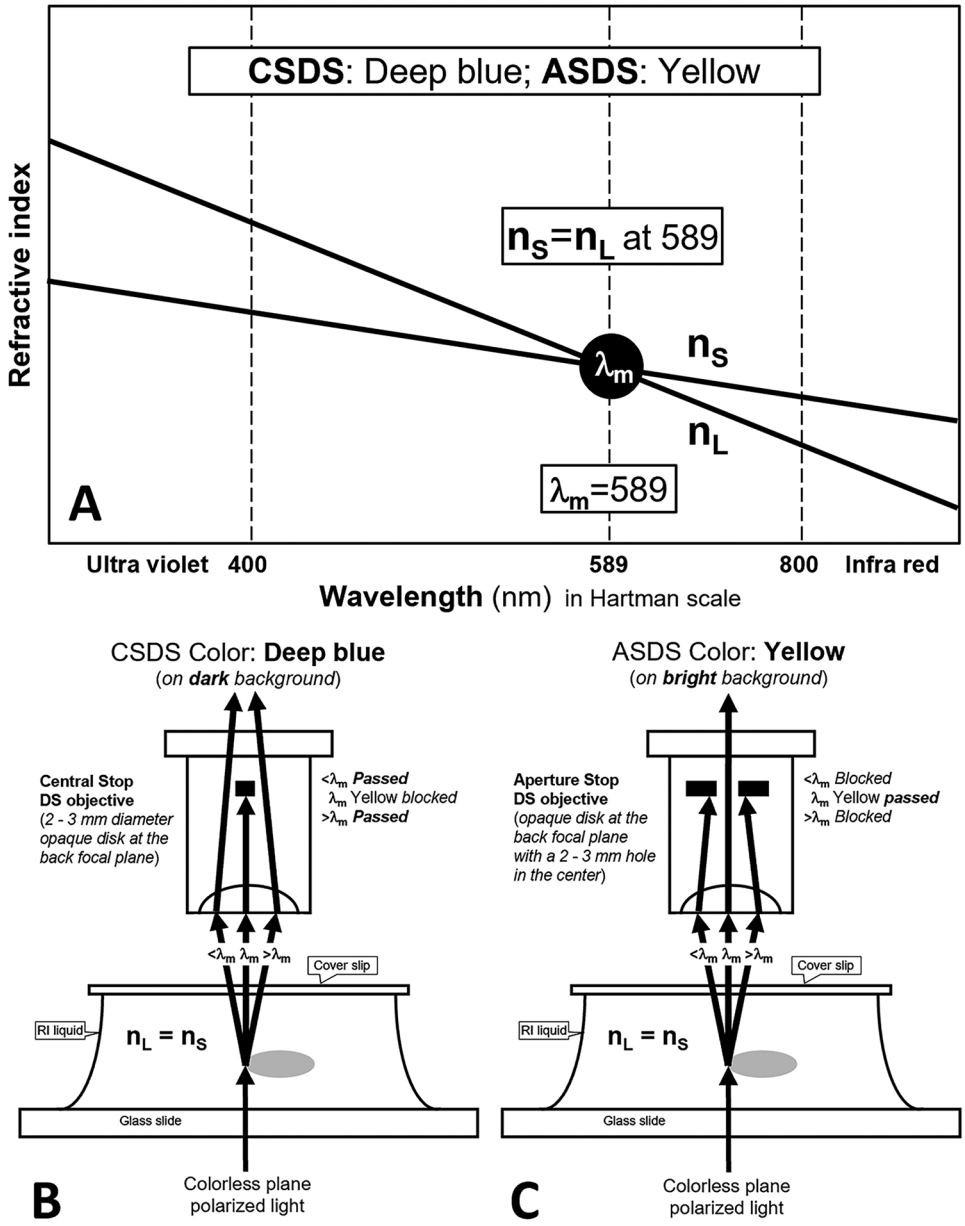

Figure 1. The principle of dispersion staining, showing the case of n_S = n_L at 589.3 nm. A) The dispersion curves of solid and liquid intersect at 589.3 nm, λ_m = 589.3 nm; B) The central stop DS mode: λ_m is blocked by the CSDS objective lens; and C) The annular stop DS mode: λ_m is allowed to pass through the ASDS objective lens.

RI is the most important optical property of non-opaque minerals. It is therefore the primary diagnostic optical property used to identify asbestos minerals. Most environmental laboratories in the U.S. and Canada participate in the National Voluntary Laboratory Accreditation Program (NVLAP) administered by the National Institute of Standards and Technology (NIST), U.S. Department of Commerce. NVLAP requires the refractive indices α and γ of asbestos fibers to be determined by the immersion technique during routine bulk asbestos sample analysis. Generally, an attainable and reasonable accuracy is $\leq$0.005 for chrysotile, amosite, tremolite, actinolite, and anthophyllite, and $\leq$0.010 for crocidolite.

In many environmental laboratories, the high volume of samples demands that analysts minimize the amount of time spent on the determination of the required optical properties, particularly the refractive

indices. It is most desirable to determine both α and γ in a single preparation. There are three common techniques for assessing the sign and magnitude of the match/mismatch between a solid and its surrounding liquid: Becke line (3), dispersion staining (4, 5), and oblique illumination (6). Only the dispersion staining (DS) can meet the above specific needs for the routine PLM analysis of bulk asbestos samples in commercial environmental laboratories.

This paper proposes a rapid procedure for asbestos analysts to convert the observed DS color associated with α or γ for a specific asbestos mineral in a specific RI liquid through its matching wavelength λ_m into the corresponding numerical RI value with desirable accuracy.

DISPERSION STAINING TECHNIQUE

To fully understand dispersion staining, it is necessary to review the following basic concepts:

- Dispersive property: A physical property changing its value with optical wavelength. Refractive index is a dispersive property. The same material exhibits different RI values at different wavelengths.
- Refractive indices of the majority of materials decrease with increasing wavelength.
- Refractive indices of all asbestos minerals and RI liquids decrease with increasing wavelength.
- Hartmann equation (7): An equation relating refractive, n, with wavelength, λ:

$$n = a + b/\lambda + c^2/\lambda^2 + \ldots$$

where, a, b, and c are constants.

A 2-term Hartmann equation, $n = a + b/\lambda$ is sufficiently accurate to describe the quantitative relationship between n and λ for the purpose of discussion.

- Visible spectrum: 400–740 nm or 4,000–7,400 Å.
- Fraunhöfer spectral lines in the visible spectrum:

F (blue)	–486.1 nm	n_F	–RI at 486.1 nm
D (yellow)	–589.3 nm	n_D	–RI at 589.3 nm
C (red)	–656.3 nm	n_C	–RI at 656.3 nm

The F, D, and C wavelengths are rounded off in Figure 1A.

- The standard wavelength used to describe the RI of a material is D (yellow) or 589.3 nm. When we say a chrysotile fiber has $\gamma = 1.556$ and $\alpha = 1.548$, it is implied that the RI is for yellow light (D or 589.3 nm wavelength).
- Dispersion coefficient (DC), $[n_F - n_C]$, describes the dispersion power of a material. The larger the value, the higher the dispersion power. Generally, liquids have a higher DC than solids.
- Dispersion curve: Plot of RI n against wavelength λ, a nearly linear curve on a Hartmann dispersion chart ($n = a + b/\lambda$).
- Matching wavelength, λ_m: The wavelength at the intersection point of the dispersion curve of a solid with that of its surrounding liquid medium; the solid and liquid have the same RI at this wavelength.

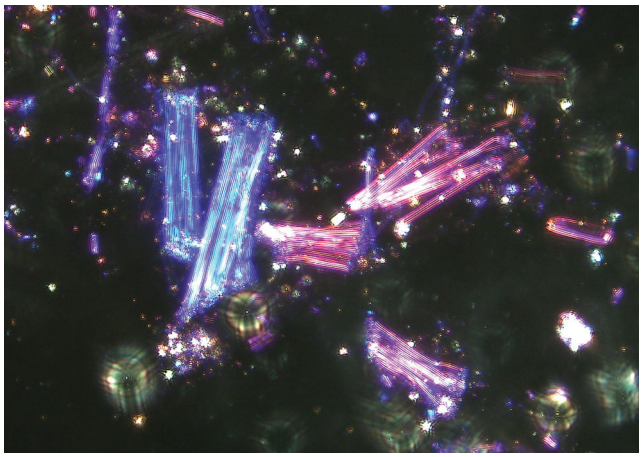

Figure 2. The CSDS colors of NIST SRM (Standard Reference Material) 1866 chrysotile ($\alpha = 1.549$; $\gamma = 1.556$) in 1.550 HD-L RI liquid from DRIMMC at 23° C.

The immersion method is an effective way to determine the RI of small solid objects. An unknown non-opaque specimen is immersed in a series of liquid media with different RI values, and its RI is compared against that of the liquid. If a match in RI between the solid and liquid is reached, the unknown solid's RI (n_D^S) is considered to be equal to the liquid's RI (n_D^L).

Dispersion staining is a technique for the quantitative evaluation of the RI match/mismatch between n_D^S and n_D^L or the sign and magnitude of ($n_D^S - n_D^L$) using a special objective lens to filter out either the matching wavelength λ_m (central stop mode) or the complementary wavelengths of λ_m (annular stop mode). Figures 1B and 1C illustrate the principle of dispersion staining. The differences between the two DS modes are summarized in Table 1 (see Tables 1–16 on pages 61–69). Because the accuracy of the DS technique is dependent on the accuracy of assessing λ_m, the central stop dispersion staining (CSDS), which transmits the complementary wavelengths of λ_m on a dark background (Figure 2), is more accurate and suitable than the annular stop dispersion staining (ASDS) mode, which transmits λ_m on a bright background, for λ_m

assessment. Some types of dispersion staining objectives are equipped with a turning wheel or slider, which has both central and annular stops. One can quickly switch between the two modes of observation and combine both CSDS and ASDS colors to get a more accurate λ_m assessment.

THE RELATIONSHIP BETWEEN THE DISPERSION STAINING COLOR AND THE REFRACTIVE INDEX

Su (8–10) established the quantitative relationship among n, λ_m, $\Delta^L = [n_F - n_C]_{liquid}$, and $\Delta^S = [n_F - n_C]_{solid}$:

$$n_D^S = n_D^L + (\Delta^L - \Delta^S) \times k_D \qquad \textbf{Equation 1}$$

where

n_D^S – the RI value of the solid at 589.3 nm;
n_D^L – the RI of the liquid at 589.3 nm and t° C;
Δ^L – the dispersion coefficient of the liquid, i.e., $[n_F - n_C]_{liquid}$;
Δ^S – the dispersion coefficient of the solid, i.e., $[n_F - n_C]_{solid}$;
k^D – a coefficient that is a function of λ_m and Fraunhöfer lines F, D, and C in accordance with the Hartmann dispersion relationship, which is equal to $[(\lambda_m - 200)^{-1} - (\lambda_D - 200)^{-1}] / [(\lambda_F - 200)^{-1} - (\lambda_C - 200)^{-1}]$ or $[(\lambda_m - 200)^{-1} - 0.002571] / 0.001304$.

1. The measurement of a solid's RI is replaced by the measurement of λ_m because both the liquid's RI and liquid's temperature are known. Dispersion staining is therefore a rapid and effective technique for assessing λ_m. That is why DS is ideally applicable for asbestos identification.

2. The solid's RI is the function of the dispersion coefficients of the solid and liquid, i.e., Δ^S and Δ^L. The Δ^S of asbestos minerals are always less than Δ^L of RI liquids.

3. For the purpose of building λ_m–t to asbestos RI conversion look-up tables, the equation is:

$$n_D^S = n_D^L + (\Delta^L - \Delta^S) \times k_D - (25 - t) \times dn/dt \qquad \textbf{Equation 2}$$

where t is the temperature of the RI liquid at measurement; dn/dt is the temperature coefficient of the liquid, a negative value.

THE HIGH DISPERSION RI LIQUIDS

The dispersion staining technique relies on the observed DS color to assess λ_m. A greater $(\Delta^L - \Delta^S)$ or greater dispersion coefficient of the RI liquid will produce more vibrant and better-defined DS colors, resulting in a more accurate λ_m.

There are two brands of high dispersion liquids on the market. Table 2 is a comparison of the dispersion coefficients of their high-dispersion series (HD for DRIMMC and E or B for Cargille) used in asbestos analysis.

On average, DRIMMC liquid's dispersion coefficient is 14.8% higher than that of Cargille liquids. For the most-frequently used 1.550 liquid, DRIMMC has two series HD-S and HD-L with almost identical dispersion coefficients. The author also found that the HD-S liquid maintains a pleasant aroma, whereas the HD-L has the pungent smell typical of conventional RI liquids.

THE DISPERSION COEFFICIENT OF ASBESTOS MINERALS

All asbestos minerals are crystalline materials and their dispersion coefficients are determined by their elemental composition and crystallographic structures. Despite the fact that the same type of asbestos minerals from different localities will have slight variations in chemistry and structure that may cause slight changes in the values of n_F, n_D, and n_C, their dispersion coefficients $[n_F - n_C]$ remain relatively stable or only slightly affected. Equation 1 indicates that if the dispersion coefficient of solid Δ^S is known, n_D^S can be derived from the observed λ_m. Therefore, based on the dispersion coefficient data of six well-characterized asbestos minerals in Table 3, it is possible to establish quantitative relationships (Tables 4 and 5) between Δ^S and λ_m, which are equally applicable to the same type of asbestos from different locations.

PROCEDURE

1. Stereomicroscopical examination.

Examine the homogenized sample under a stereomicroscope. Based on the morphology and color, an initial identification can usually be reached for the type of asbestos present in the sample.

2. Check the alignment of the polarized light microscope.

Make sure that the microscope is properly aligned:

- DS objective and its central stop is centered;
- substage condenser is centered (if possible, set the microscope according to Köhler illumination principles); and
- the vibration (or privileged) directions of

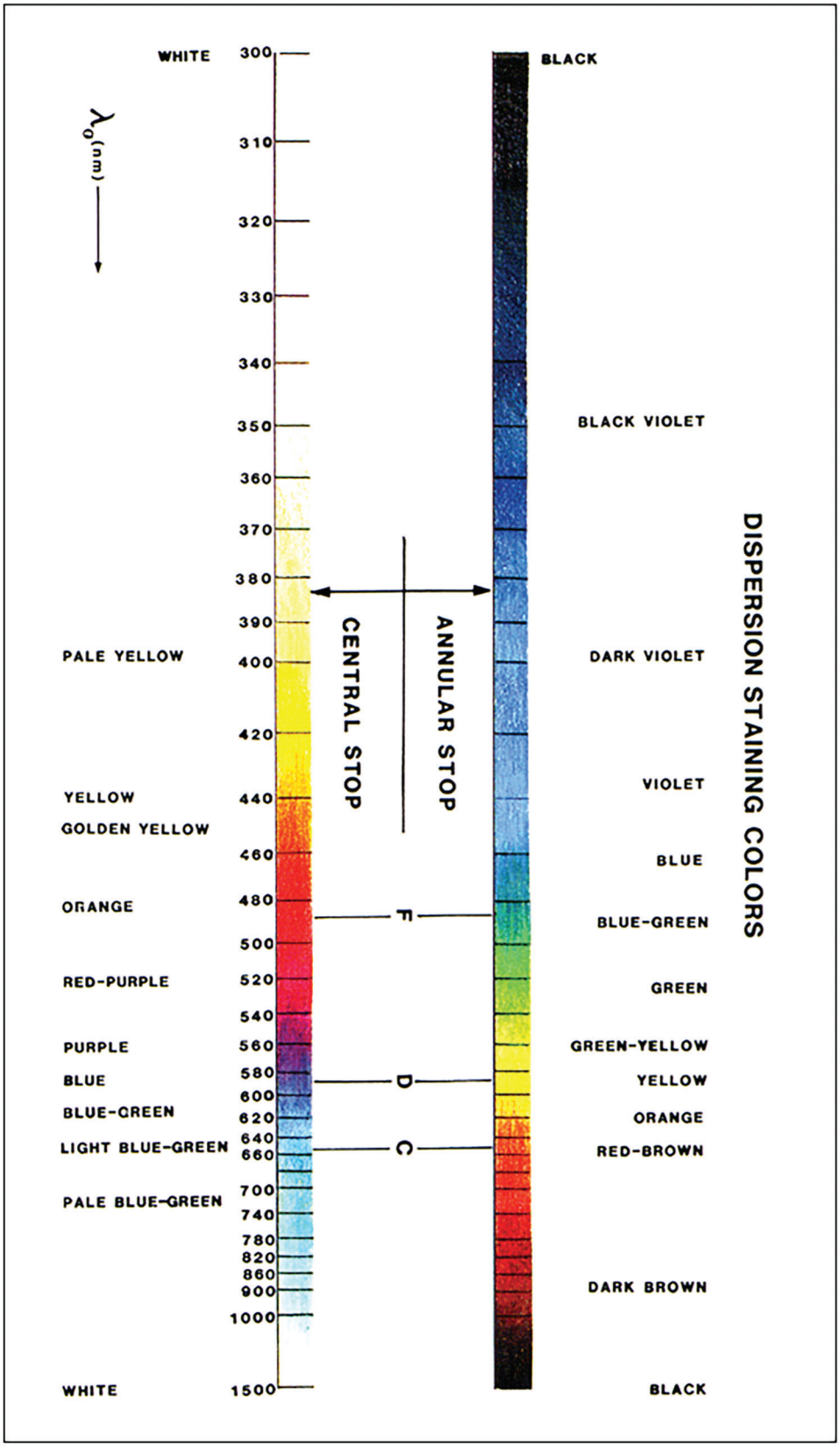

Figure 3. Converting dispersion staining color to corresponding λ_m, i.e., λ_0 in the chart (5).

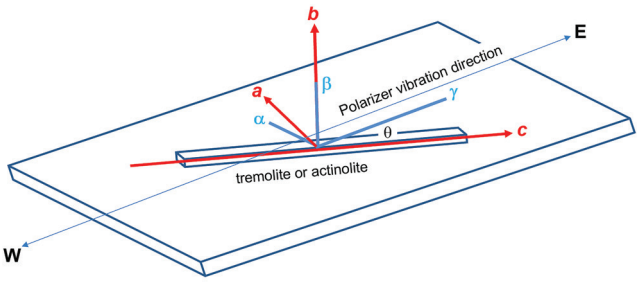

Figure 4. Optical orientation of tremolite and actinolite.

polarizer and analyzer are parallel to the E–W and N–S crosslines in the eyepiece, respectively.

3. Select a proper RI liquid to mount the sample.

Mount the suspected asbestos fibers in an appropriate RI liquid according to Table 6 DRIMMC liquid (13) or Table 7 Cargille liquid (14), which lists two cases: 1) for regulatory, legal, forensic, etc., which requires higher accuracy, and 2) for routine commercial analysis with less stringent accuracy requirements. For high-accuracy measurements such as regulatory, legal, and forensic analysis, etc., the rule of thumb is to choose RI liquids as close as possible to the RI's that will be measured. For example, there are chrysotile minerals whose RIs are significantly higher than those of the standard chrysotile from the NIST SRM 1866 set. In that case, 1.555 or 1.560, instead of 1.550, RI liquids should be used to determine γ (Table 6). When efficiency is a priority and the accuracy requirement is less stringent, choose an RI liquid higher than α and lower than γ so that the two RIs can be determined in a single preparation.

It is imperative to have a fresh surface of asbestos fibers in direct contact with the surrounding RI liquid. Sometimes, the surface of an asbestos bundle may be coated with matrix or binder materials. In this case, true DS colors may not be properly displayed. A simple and effective way to bring out the true DS colors is to grind or rub the fiber bundle with a steel needle or probe to break the fiber bundle into finer bundles to reveal some fresh surface in direct contact with the surrounding liquid.

4. Measure the temperature of the RI liquid.

Measure and record t (in °C) corresponding to the temperature of the RI liquid on the microscope slide. If the temperature of the liquid, slide, cover glass, and sample can be reasonably assumed to be in equilibrium with the room temperature, t can be assumed to be equal to the room temperature. The temperature data is needed for making a temperature correction. The light source of certain microscope might heat up the microscope stage and slide, resulting in an increase of 2° C or more in the liquid temperature.

5. Observe the central stop DS color associated with γ of the asbestos fibers.

Assuming the polarizer's linear vibration direction is E–W, refer to Table 8 to orient the asbestos fiber for measurement. It is simple to locate both α and γ for chrysotile, amosite, and crocidolite, all of which exhibit "uniaxial" characteristics, by following the description in Table 8. A small range of DS colors is usually displayed. Record the prevalent CSDS color (Figure 3) as the measure of λ_m of α.

It is not easy, however, to locate α and γ for tremolite and actinolite, both of which exhibit monoclinic extinction characteristics. Their fibrous morphology makes it even harder to do so because it is impossible to obtain the interference figure of a fine fiber or fiber bundle to locate α or γ. The only measurable property related to the γ location is the extinction angle θ. For tremolite and actinolite, γ and α are in the a–c crystallographic plane, i.e., the plane containing both a- and c-axes, or (010) plane, in which γ exhibits a maximum extinction angle to the c-axis, the fiber elongation axis (Figure 4).

By definition, the extinction angle is defined as the acute angle between γ and the fiber elongation axis (c-axis for tremolite and actinolite). Because thin fibers in a RI liquid can rotate freely around their elongation axes, a randomly chosen tremolite or actinolite fiber may not exhibit its true extinction angle but a range of extinction angles from 0° (parallel extinction) up to its true extinction angle, which may be 20° or more; it is mostly between 15° and 18° (15) Rotate a tremolite or actinolite fiber to the extinction position near the E–W crossline (with an E–W polarizer) and measure its extinction angle relative to the E–W crossline. After measuring at least a dozen or more oblique extinction fibers, the one that exhibits the largest extinction angle is the fiber having a RI statistically closest to the true γ. Record its CSDS color as a measurement of the true γ. Once γ is found, one can rotate the fiber 90° and α is now parallel to the E–W polarizer. The CSDS color of α can now be recorded.

It is not always possible to locate the true γ because the fiber with the largest extinction angle statistically may not be the true γ but a γ' close to γ. It will be necessary to evaluate the possible deviation of a γ' from γ if the apparent (observed) extinction angle is less than the true extinction angle. Figure 5

is the α–γ section of the optical indicatrix of tremolite or actinolite, which contains the c-axis. θ is the true extinction angle. The γ' values for any direction between γ and c can be easily calculated. Table 9 is the calculation of the possible RI (γ') values and their deviations from the true γ value (γ–γ') for a randomly-chosen oblique extinction fiber when the fiber has an extinction angle of 20°. According to Table 9, any oblique extinction fiber's γ' will not deviate from the true γ by more than 0.0035, well within the acceptable absolute error of 0.005 or higher required by NVLAP in its biannual proficiency testing. Therefore, it can be concluded that, as long as an oblique extinction fiber with a distinctive extinction angle is measured, its γ' value will meet the NVLAP accuracy requirements for γ; the same conclusion is true for α.

6. Convert the observed DS color into the corresponding matching wavelength λ_m between the asbestos fiber and the RI liquid used by referring to Table 10 and Figure 3.

Unlike Figure 3, the increments of the matching wavelength in Table 10 are not a uniform 20 nm (for the most part). The increments in Table 10 are coarser than those of Figure 3. For example, if an observed CSDS color is yellow-orange, which does not fall right on a specific color but between two adjacent colors: golden yellow (455 nm) and orange (485 nm). The color can be interpolated as 470 nm. For an experienced analyst, one can assign the color to be 460 nm if closer to golden yellow or 480 nm if closer to orange.

7. Find out the numerical value of γ corresponding to the observed λ_m and t.

Search the conversion look-up table, e.g., Table 4 (DRIMMC liquid) or Table 5 (Cargille liquid) for chrysotile, or the attached conversion tables for other asbestos minerals (listed in Table 11 and downloadable by scanning the QR code on page 51) to convert the observed λ_m and t into the corresponding numerical value of the RI γ.

Dispersion staining does not require that the RI of the liquid match the solid's RI at exactly 589.3 nm, i.e., $n_D^S = n_D^L$; n_D^L could be lower or higher than n_D^S as long as λ_m is within the visible range 400 to 740 nm. DS exhibits (n_D^S–n_D^L) as a DS color, which is a function of (n_D^S– n_D^L). In other words, the DS color tells us whether n_D^S is lower or higher than n_D^L and by how much (Equation 1). Because n_D^L is known, n_D^S is then determined. All required computations by Equation 1 are built into the look-up Table 4 (DRIMMC liquids) or Table 5 (Cargille liquids) to facilitate the quick solution of n_D^S.

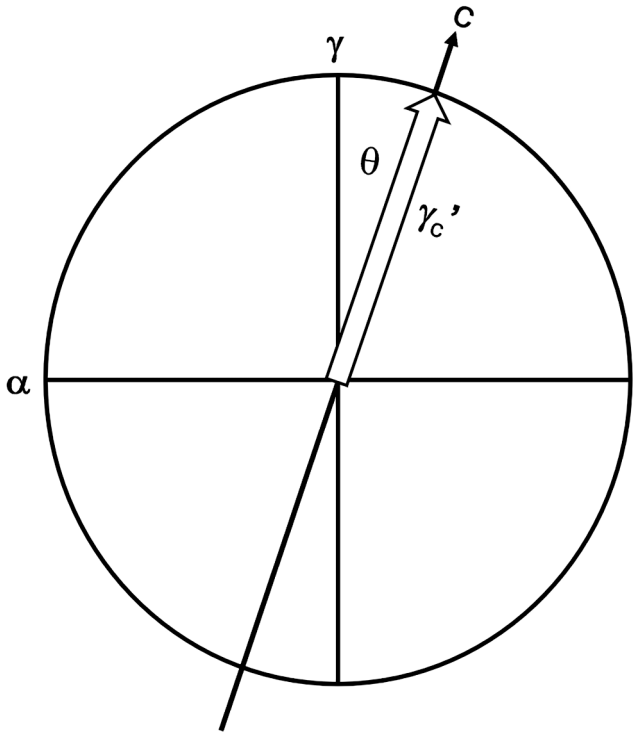

Figure 5. In this α–γ section of the optical indicatrix of tremolite and actinolite, the RI value of a direction is equal to the corresponding radius of the ellipse, e.g., the RI along the c-axis or the fiber elongation axis is the radius γ_c'. The extinction angle is θ, i.e., the angle between γ and c. Any fiber that exhibits an apparent (observed) extinction angle less than θ will have an RI (γ') equivalent to its corresponding radius between γ and γ_c' (Table 9).

8. Observe the DS color associated with α of the asbestos fibers.

For chrysotile, amosite, and crocidolite, rotate the fiber 90° from the γ position to measure α. Again, a range of DS colors is usually displayed. Record the prevalent CSDS color (e.g., Figure 2 for chrysotile) as the measure of α.

For tremolite or actinolite, as mentioned in procedure No. 5, the direction 90° from γ is α. For anthophyllite, trial and error is still the only viable approach to finding α. Align the fiber parallel to the N–S crossline with an E–W polarizer. At this position, the RI displayed could be any value between α and β, most likely α'. Measure at least a dozen fibers, and the longest matching wavelength color (Table 10 and Figure 3), i.e., corresponding to the lowest RI value, is the closest to α.

9. Convert the observed DS color into the corresponding matching wavelength λ_m between the asbestos

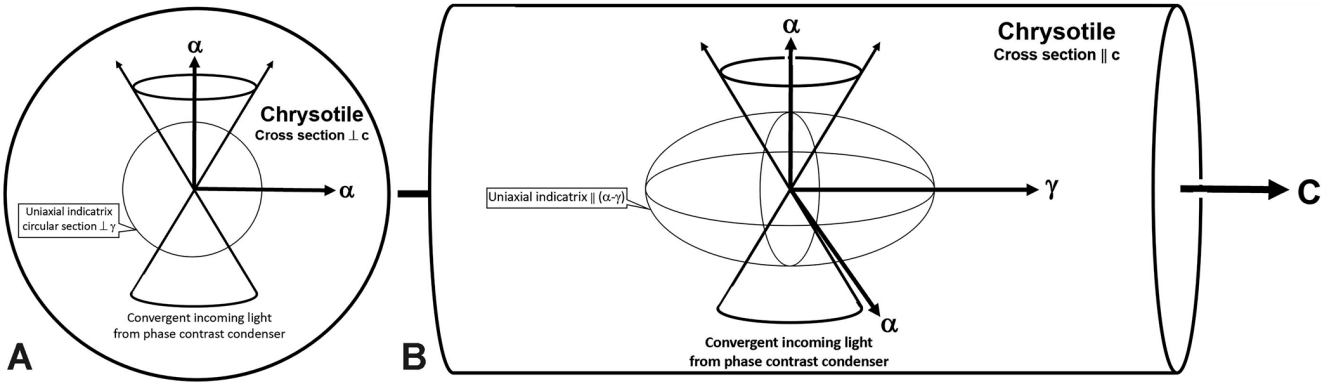

Figure 6. Cross sections of the indicatrix of chrysotile: A) ⊥ γ and B) || ($\alpha-\gamma$).

fiber and the RI liquid used by referring to Table 10 and Figure 3.

Although both Table 10 and Figure 3 are capable of converting DS colors into the corresponding λ_m, Table 10 is preferred because the colors of Figure 3 are affected by quite a few factors, such as the color temperature of the microscope light source, intensity of the incident light, printer's color fidelity, etc.

10. Find out the numerical value of α corresponding to the observed λ_m and t.

Search the conversion table, e.g., Table 4 (DRIMMC liquid) or Table 5 (Cargille liquid) for chrysotile, or conversion tables for other asbestos minerals (listed in Table 11 and downloadable by scanning the QR code on page 51) to convert the observed λ_m and t into the corresponding numerical value of RI γ.

HIGH-MAGNIFICATION DISPERSION STAINING OBJECTIVE AND PHASE CONTRAST DISPERSION STAINING

The best result for the DS technique is obtained using a 10× objective lens because its small (0.17–0.25) numerical aperture (NA) is best suited to achieve an axial light beam. The paramount importance of using an axial light beam in RI measurement cannot be overemphasized. However, sometimes the specimen particle is so minute, higher magnification objectives are desirable. To meet this demand primarily in asbestos analysis, a microscope manufacturer introduced a 40× DS objective lens with an NA = 0.75 (16), which generates a 97° light cone to illuminate the whole field of view. This light cone contains a wave normal whose angle to the plane of the slide ranges from 0° to 42°. For isotropic crystals, its optical indicatrix (7, 17) is a sphere, meaning every direction exhibits the same RI. The circular cross section of the uniaxial optical indicatrix perpendicular is similar to the c crystallographic axis. Mineralogically speaking, chrysotile is a monoclinic crystal and biaxial. Because of the strain-related deformation in the crystal structure, the asbestiform chrysotile forms a tabular fibril that is composed of concentrically or spirally curved layers (18). It behaves optically like a uniaxial crystal with two principal refractive indices, ω (equivalent to α) and ε (equivalent to γ), with a singular circular section perpendicular to γ, i.e., the c-axis (Figure 6A). Only in the case of an isotropic crystal or the circular section of a uniaxial crystal, is a conical convergent beam capable of measuring the target RI, i.e., n for isotropic and ω (α) for uniaxial. It is acceptable for an analyst to use a 40× DS objective to measure α of chrysotile. It is not acceptable, however, to use the same objective to measure γ of chrysotile because the wave normal is up to ≈42° in the conical convergent beam, and so it is not parallel to the γ direction. The RI measured by the range of the wave normal is γ' instead of the true γ (Figure 6B).

Therefore, the 40× DS objective is capable of measuring α of chrysotile but not the true γ. From a mineralogy standpoint, it is incapable of measuring α and γ of the five amphibole asbestos minerals because their crystallographic systems are either monoclinic or orthorhombic. For monoclinic and orthorhombic asbestos minerals, the 40× DS objective can only measure α' and γ' instead of true α and true γ.

Yet for practical reasons, it must be pointed out that in the case of fibers exhibiting low birefringence recording γ' may be within the NVLAP-acceptable error for γ (see the error estimate in Table 9). And it is acceptable to use the 40× DS objective for RI measurement of asbestos minerals even though one is not measuring the true α or γ but an α' reasonably close to the true α and a γ' reasonably close to the true γ.

The above analysis is equally applicable to phase contrast DS, whose light path is illustrated in Figure 7. The highly convergent incoming light beams will result in a highly convergent wave normal cone, which can only measure chrysotile's α but not γ. Nor can it measure the true α and γ of any biaxial crystals, such as the five amphibole asbestoses.

Again, for practical reasons, in the case of fibers exhibiting low birefringence recording γ' may be within the NVLAP-acceptable error for γ (see the error estimate in Table 9). And it is acceptable to use phase contrast dispersion staining for RI measurement of asbestos minerals even though one is not measuring the true α or γ but an α' reasonably close to the true α and a γ' reasonably close to the true γ.

CALIBRATION OF RI LIQUIDS USING CARGILLE OPTICAL GLASS STANDARDS

To ensure the accuracy of measurement, it is necessary to make sure that the RI liquids used have correct RI values. The calibration of RI liquids can only be accurately performed using an Abbe refractometer. When an Abbe refractometer is not available, an alternative means of calibration (in fact it is not a calibration in its strict sense but practically a verification) is by using optical glasses that have accurate and precise RI values, such as the optical glass standards manufactured by Cargille (20). Since the NVLAP program uses "calibration" in its documents and allows the use of optical glass standards, we can follow NVLAP program usage, yet it is actually a "verification" of whether an RI liquid is within ±0.004 of its $n_D^{25°}$ C value. There are three Cargille Reference Sets on the market: M-7, M-24, and M-25 (14). Table 12 summarizes the parameters of Cargille glasses suitable for RI liquid calibration. There are many overlaps among the three sets with the same or different lot numbers.

The procedure for the calibration of RI liquids using optical glass standards is similar to the above procedure for the measurement of RI of asbestos minerals using RI liquids. In asbestos identification, a liquid with known RI is the "known," and the asbestos mineral's RI is the "unknown" to be measured. In the RI liquid calibration, the role is reversed: the optical glass standard with known RI is the "known," and the RI of the liquid is the "unknown" to be measured. Therefore, their operational procedures are the same. However, the equation used in generating the look-up conversion tables is different in terms of the sign of the temperature correction.

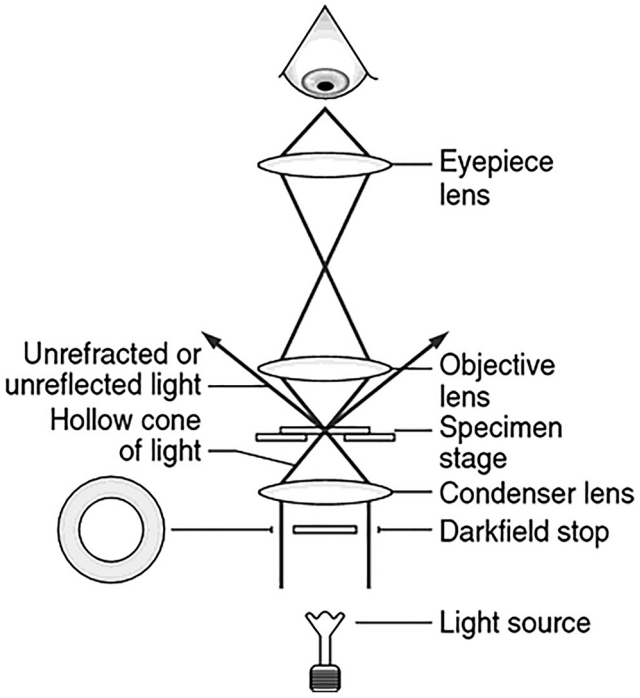

Figure 7. The light path of phase contrast microscope (19).

$$n_D^S = n_D^L + (DL–DS) \times k_D + (25–T) \times dn/dt \quad \textbf{Equation 3}$$

After finding the matching wavelength λ_m at temperature t, the RI of liquid at D wavelength (589.3 nm) and 25° C can be read from the look-up conversion tables in Table 13 (DRIMMC liquid) or Table 14 (Cargille liquid), which are built using Equation 3 for the liquid-glass combinations in Table 15. Table 16 is a recommended form for recording RI liquid calibration results using Cargille glass standards.

SUMMARY

1. Dispersion staining is an effective technique for quantifying the RI difference between a non-opaque solid and its surrounding RI liquid medium. Between the two modes of DS, central stop dispersion staining is the most suitable for routine analysis in bulk asbestos identification.

2. In the majority of cases, one bulk sample preparation is sufficient to measure both α and γ to the desired accuracy required by NVLAP. For NVLAP proficiency testing, separate RI liquids for α and γ are recommended (Tables 6 and 7).

3. A full suite of 40 conversion look-up tables has been developed to facilitate the conversion of the observed matching wavelength λ_m, and temperature t,

to the corresponding refractive index value for the six regulated asbestos minerals. Those tables can be downloaded by scanning the QR code on page 51.

4. The RI liquids from DRIMMC have relatively higher dispersion coefficients than other RI liquids and are capable of producing more vibrant and better-defined dispersion staining colors leading to better accuracy in the assessment of the matching wavelength λ_m. The author also found that the HD-S 1.550 liquid maintains a pleasant aroma, without the pungent smell typical of conventional RI liquids.

5. Despite the fact that the high-magnification DS objective lens is only adequate to measure chrysotile's α but not its γ, or the α or γ of the five amphiboles, it is practically capable of obtaining an α' reasonably close to the true α in the case of amphiboles and a γ' reasonably close to the true γ in the case of chrysotile and amphiboles. The same is true for the high-magnification phase contrast objective lens.

6. In the absence of an Abbe refractometer, RI liquids can be calibrated (verified) using optical glass standards. Twenty-two comprehensive conversion look-up tables for both DRIMMC and Cargille RI liquids have been constructed and can be downloaded by scanning the QR code on page 51.

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See Tables 1–16 on pages 61–69

Table 1. Comparison of the Two Modes of Dispersion Staining Techniques

Mode of dispersion staining		**Central Stop**	**Annular Stop**
Objective lens used		Central stop	Annular stop
Wavelengths observed		$(<\lambda_m) + (>\lambda_m)$	λ_m
DS color observed at different n_S vs. n_L relationship	$n_S >> n_L$	Ver pale yellow	Black violet
	$n_S > n_L$	Yellowish-reddish	Bluish-greenish
	$n_S = n_L$	Deep blue	Yellow
	$n_S < n_L$	Bluish-greenish	Orangish-brownish
	$n_S << n_L$	Very pale blue-green	Black brown
Background		Darkfield	Brightfield
Accuracy of assessing λ_m		Higher	Lower

Table 2. Dispersion Coefficients of DRIMMC and Cargille RI Liquids

RI Liquid	**1.550**	**1.605**	**1.610**	**1.615**	**1.620**	**1.625**	**1.630**	**1.635**	**1.640**	**1.680**	**1.700**
DRIMMC[1]	HD-S	HD-L	HD-L	HD-L	HD-L	HD-L	HD-L	HD-L	HD-L	HD-L	HD-L
	0.0274	0.0313	0.0315	0.0319	0.0323	0.0327	0.0328	0.0332	0.0338	0.0383	0.0378
Cargille[2]	E	E	E	E	E	E	E	E	E	B	B
	0.0267	0.0243	0.0251	0.0259	0.0275	0.0275	0.0283	0.0291	0.0299	0.0348	0.0370

[1]Manufactured by Delaware Research Institute of Microscopy and Material Characterization LLC.
[2]Manufactured by Cargille Laboratory.

Table 3. Refractive Indices and Dispersion Coefficients [n_F–n_C] of Six Asbestos Minerals

Asbestos	**RI**	n_F	n_D	n_C	$[n_F–n_C]$	**Reference**
Chrysotile	α	1.5563	1.5486	1.5455	0.0107*	NIST SRM 1866 (11)
	γ	1.5649	1.5564	1.5531	0.0119*	
Grunerite (Amosite)	α	1.6937	1.6790	1.6731	0.0206	
	γ	1.7157*	1.7010	1.6951	0.0206*	
Riebeckite (Crocidolite)	α	1.7132	1.7015	1.6971	0.0161	Figures 104A, 104B (5)
	γ	1.7206	1.7072	1.7032	0.0174	
Tremolite	α	1.6128	1.6063	1.6036	0.0092	NIST SRM 1867 (12)
	β	1.6299	1.6230	1.6201	0.0098	
	γ	1.6423	1.6343	1.6310	0.0113	
Actinolite	α	1.6201	1.6126	1.6095	0.0106	
	β	1.6369	1.6288	1.6254	0.0115	
	γ	1.6485	1.6393	1.6355	0.0130	
Anthophyllite	α	1.6227	1.6148	1.6116	0.0111	
	β	1.6350	1.6273	1.6241	0.0109	
	γ	1.6449	1.6362	1.6326	0.0123	

*Recalculated from the regression analysis of SRM 1866 original data.

Table 4. λ_m and t to RI Conversion for Chrysotile in DRIMMC 1.550 (HD-S or L)

λ_m (nm)	α							γ						
	17° C	19° C	21° C	23° C	25° C	27° C	29° C	17° C	19° C	21° C	23° C	25° C	27° C	29° C
300	1.648	1.647	1.646	1.645	1.644	1.643	1.642	1.641	1.640	1.639	1.638	1.637	1.636	1.635
320	1.627	1.626	1.625	1.624	1.623	1.622	1.621	1.622	1.621	1.620	1.619	1.618	1.617	1.616
340	1.612	1.611	1.610	1.609	1.608	1.607	1.606	1.608	1.607	1.606	1.605	1.604	1.603	1.602
360	1.601	1.600	1.599	1.598	1.597	1.596	1.595	1.597	1.596	1.595	1.594	1.593	1.592	1.591
380	1.592	1.591	1.590	1.589	1.588	1.587	1.586	1.589	1.588	1.587	1.586	1.585	1.584	1.583
400	1.585	1.584	1.583	1.582	1.581	1.580	1.579	1.582	1.581	1.580	1.579	1.578	1.578	1.577
420	1.579	1.578	1.577	1.576	1.575	1.574	1.573	1.577	1.576	1.575	1.574	1.573	1.572	1.571
440	1.574	1.573	1.572	1.571	1.570	1.569	1.568	1.573	1.572	1.571	1.570	1.569	1.568	1.567
460	1.570	1.569	1.568	1.567	1.566	1.565	1.564	1.569	1.568	1.567	1.566	1.565	1.564	1.563
480	1.567	1.566	1.565	1.564	1.563	1.562	1.561	1.566	1.565	1.564	1.563	1.562	1.561	1.560
500	1.564	1.563	1.562	1.561	1.560	1.559	1.558	1.563	1.562	1.561	1.560	1.559	1.558	1.557
520	1.561	1.560	1.559	1.558	1.557	1.556	1.555	1.560	1.559	1.558	1.557	1.557	1.556	1.555
540	1.559	1.558	1.557	1.556	1.555	1.554	1.553	1.558	1.557	1.556	1.555	1.554	1.553	1.552
560	1.557	1.556	1.555	1.554	1.553	1.552	1.551	1.556	1.555	1.554	1.553	1.552	1.551	1.550
580	1.555	1.554	1.553	1.552	1.551	1.550	1.549	1.555	1.554	1.553	1.552	1.551	1.550	1.549
600	1.553	1.552	1.551	1.550	1.549	1.548	1.547	1.553	1.552	1.551	1.550	1.549	1.548	1.547
620	1.552	1.551	1.550	1.549	1.548	1.547	1.546	1.552	1.551	1.550	1.549	1.548	1.547	1.546
640	1.550	1.549	1.548	1.547	1.546	1.545	1.544	1.550	1.549	1.548	1.547	1.547	1.546	1.545
660	1.549	1.548	1.547	1.546	1.545	1.544	1.543	1.549	1.548	1.547	1.546	1.545	1.544	1.543
680	1.548	1.547	1.546	1.545	1.544	1.543	1.542	1.548	1.547	1.546	1.545	1.544	1.543	1.542
700	1.547	1.546	1.545	1.544	1.543	1.542	1.541	1.547	1.546	1.545	1.544	1.543	1.542	1.541
720	1.546	1.545	1.544	1.543	1.542	1.541	1.540	1.546	1.545	1.544	1.543	1.542	1.541	1.540
740	1.545	1.544	1.543	1.542	1.541	1.540	1.539	1.546	1.545	1.544	1.543	1.542	1.541	1.540
760	1.544	1.543	1.542	1.541	1.540	1.539	1.538	1.545	1.544	1.543	1.542	1.541	1.540	1.539
780	1.543	1.542	1.541	1.540	1.539	1.538	1.537	1.544	1.543	1.542	1.541	1.540	1.539	1.538
800	1.543	1.542	1.541	1.540	1.539	1.538	1.537	1.543	1.542	1.541	1.540	1.539	1.538	1.537
850	1.541	1.540	1.539	1.538	1.537	1.536	1.535	1.542	1.541	1.540	1.539	1.538	1.537	1.536
900	1.539	1.539	1.538	1.537	1.536	1.535	1.534	1.541	1.540	1.539	1.538	1.537	1.536	1.535
950	1.538	1.537	1.536	1.535	1.534	1.533	1.532	1.539	1.538	1.537	1.536	1.535	1.534	1.534
1000	1.537	1.536	1.535	1.534	1.533	1.532	1.531	1.538	1.537	1.536	1.535	1.535	1.534	1.533

Table 5. λ_m and t to RI Conversion for Chrysotile in Cargille 1.550 (E) — CORRECTED

λ_m (nm)	α								γ						
	17° C	19° C	21° C	23° C	25° C	27° C	29° C		17° C	19° C	21° C	23° C	25° C	27° C	29° C
300	1.645	1.644	1.643	1.642	1.641	1.640	1.639		1.638	1.637	1.636	1.635	1.634	1.633	1.632
320	1.625	1.624	1.623	1.622	1.621	1.620	1.619		1.619	1.618	1.617	1.616	1.615	1.614	1.613
340	1.610	1.609	1.608	1.607	1.606	1.605	1.604		1.606	1.605	1.604	1.603	1.602	1.601	1.600
360	1.599	1.598	1.597	1.596	1.595	1.594	1.593		1.596	1.595	1.594	1.593	1.592	1.591	1.590
380	1.591	1.590	1.589	1.588	1.587	1.586	1.585		1.588	1.587	1.586	1.585	1.584	1.583	1.582
400	1.584	1.583	1.582	1.581	1.580	1.579	1.578		1.581	1.581	1.580	1.579	1.578	1.577	1.576
420	1.578	1.577	1.576	1.575	1.574	1.573	1.572		1.576	1.575	1.574	1.573	1.572	1.571	1.570
440	1.573	1.573	1.572	1.571	1.570	1.569	1.568		1.572	1.571	1.570	1.569	1.568	1.567	1.566
460	1.570	1.569	1.568	1.567	1.566	1.565	1.564		1.568	1.567	1.566	1.565	1.564	1.563	1.563
480	1.566	1.565	1.564	1.563	1.562	1.561	1.560		1.565	1.564	1.563	1.562	1.561	1.560	1.559
500	1.563	1.562	1.561	1.560	1.559	1.558	1.557		1.563	1.562	1.561	1.560	1.559	1.558	1.557
520	1.561	1.560	1.559	1.558	1.557	1.556	1.555		1.560	1.559	1.558	1.557	1.556	1.555	1.554
540	1.558	1.557	1.557	1.556	1.555	1.554	1.553		1.558	1.557	1.556	1.555	1.554	1.553	1.552
560	1.556	1.555	1.554	1.554	1.553	1.552	1.551		1.556	1.555	1.554	1.553	1.552	1.551	1.550
580	1.555	1.554	1.553	1.552	1.551	1.550	1.549		1.555	1.554	1.553	1.552	1.551	1.550	1.549
600	1.553	1.552	1.551	1.550	1.549	1.548	1.547		1.553	1.552	1.551	1.550	1.549	1.548	1.547
620	1.552	1.551	1.550	1.549	1.548	1.547	1.546		1.552	1.551	1.550	1.549	1.548	1.547	1.546
640	1.550	1.549	1.548	1.547	1.546	1.545	1.544		1.551	1.550	1.549	1.548	1.547	1.546	1.545
660	1.549	1.548	1.547	1.546	1.545	1.544	1.543		1.549	1.548	1.547	1.546	1.545	1.545	1.544
680	1.548	1.547	1.546	1.545	1.544	1.543	1.542		1.548	1.547	1.546	1.545	1.544	1.543	1.543
700	1.547	1.546	1.545	1.544	1.543	1.542	1.541		1.547	1.546	1.545	1.544	1.544	1.543	1.542
720	1.546	1.545	1.544	1.543	1.542	1.541	1.540		1.547	1.546	1.545	1.544	1.543	1.542	1.541
740	1.545	1.544	1.543	1.542	1.541	1.540	1.539		1.546	1.545	1.544	1.543	1.542	1.541	1.540
760	1.544	1.543	1.542	1.541	1.540	1.539	1.538		1.545	1.544	1.543	1.542	1.541	1.540	1.539
780	1.544	1.543	1.542	1.541	1.540	1.539	1.538		1.544	1.543	1.542	1.541	1.540	1.539	1.538
800	1.543	1.542	1.541	1.540	1.539	1.538	1.537		1.544	1.543	1.542	1.541	1.540	1.539	1.538
850	1.541	1.540	1.539	1.538	1.537	1.536	1.535		1.542	1.541	1.540	1.539	1.538	1.537	1.536
900	1.540	1.539	1.538	1.537	1.536	1.535	1.534		1.541	1.540	1.539	1.538	1.537	1.536	1.535
950	1.539	1.538	1.537	1.536	1.535	1.534	1.533		1.540	1.539	1.538	1.537	1.536	1.535	1.534
1000	1.538	1.537	1.536	1.535	1.534	1.533	1.532		1.539	1.538	1.537	1.536	1.535	1.534	1.533

Table 6. Selection of DRIMMC Immersion Liquids for Asbestos Analysis

Asbestos	RI	High Accuracy Required (regulatory, litigation, forensic, etc.)	Routine Samples
Chrysotile	α	1.546 / 1.550 (HD or HD-L)*	1.550 (HD-S or L)
	γ	1.550 / 1.560 (HD or HD-L)*	
Grunerite (Amosite)	α	1.680 (HD or HD-L)	1.680 (HD or HD-L)
	γ	1.700 (HD or HD-L)	
Riebeckite (Crocidolite)	α	1.700 (HD or HD-L)	1.680 (HD or HD-L)
	γ	1.680 (HD or HD-L)	
Tremolite	α	1.605 / 1.610 / 1.615 (HD or HD-L)	1.620 (HD or HD-L) or 1.625 (HD or HD-L)
	γ	1.630 / 1.635 (HD or HD-L)	
Actinolite	α	1.605 / 1.610 / 1.615 (HD or HD-L)	
	γ	1.635 / 1.640 (HD or HD-L)	
Anthophyllite	α	1.605 / 1.610 / 1.615 (HD or HD-L)	
	γ	1.630 / 1.635 / 1.640 (HD or HD-L)	

*There are chrysotile minerals whose refractive indices are higher than those of the NIST SRM 1866 chrysotile.

Table 7. Selection of Cargille RI Liquids for Asbestos Analysis

Asbestos	RI	High Accuracy Required (regulatory, litigation, forensic, etc.)	Routine Samples
Chrysotile	α	1.546 / 1.550 (E)*	1.550 (E)
	γ	1.550 / 1.560 (E)*	
Grunerite (Amosite)	α	1.680 (B)	1.680 (E)
	γ	1.700 (B)	
Riebeckite (Crocidolite)	α	1.700 (B)	1.680 (E)
	γ	1.680 (B)	
Tremolite	α	1.605 / 1.610 / 1.615 (E)	1.620 (E) or 1.625 (E)
	γ	1.630 / 1.635 (E)	
Actinolite	α	1.605 / 1.610 / 1.615 (E)	
	γ	1.635 / 1.640 (E)	
Anthophyllite	α	1.605 / 1.610 / 1.615 (E)	
	γ	1.630 / 1.635 / 1.640 (E)	

*There are chrysotile minerals whose refractive indices are higher than those of the NIST SRM 1866 chrysotile.

Table 8. Fiber Orientation for Measuring α and γ (Assuming an E–W Polarizer)

Asbestos	Fiber Orientation		Remarks
	α	γ	
Chrysotile	N–S	E–W	—
Amosite	N–S	E–W	—
Crocidolite	E–W	N–S	The only negative sign of elongation asbestos.
Tremolite	Nearly N–S	Nearly E–W	Maximum extinction angle for γ; 90° from γ is α.
Actinolite	Nearly N–S	Nearly E–W	Maximum extinction angle for γ; 90° from γ is α.
Anthophyllite	N–S	E–W	E–W is γ; longest λ_m in N–S is α.

Table 9. Relationship Between γ' Value and Its Angle to γ for Tremolite and Actinolite

Asbestos		Tremolite			Actinolite		
Apparent Extinction Angle (°)	Angle Between γ and γ' (°)	γ	γ'	$\gamma - \gamma''$	γ	γ'	$\gamma - \gamma''$
20*	0	1.6423	1.6423	0.0000	1.6485	1.6485	0.0000
19	1	1.6423	1.6423	0.0000	1.6485	1.6485	0.0000
18	2	1.6423	1.6423	0.0000	1.6485	1.6485	0.0000
17	3	1.6423	1.6422	0.0001	1.6485	1.6484	0.0001
16	4	1.6423	1.6422	0.0001	1.6485	1.6484	0.0001
15	5	1.6423	1.6421	0.0002	1.6485	1.6483	0.0002
14	6	1.6423	1.6420	0.0003	1.6485	1.6482	0.0003
13	7	1.6423	1.6418	0.0005	1.6485	1.6481	0.0004
12	8	1.6423	1.6417	0.0006	1.6485	1.6479	0.0006
11	9	1.6423	1.6416	0.0007	1.6485	1.6478	0.0007
10	10	1.6423	1.6414	0.0009	1.6485	1.6476	0.0009
9	11	1.6423	1.6412	0.0011	1.6485	1.6474	0.0011
8	12	1.6423	1.6410	0.0013	1.6485	1.6472	0.0013
7	13	1.6423	1.6408	0.0015	1.6485	1.6470	0.0015
6	14	1.6423	1.6405	0.0018	1.6485	1.6468	0.0017
5	15	1.6423	1.6403	0.0020	1.6485	1.6466	0.0019
4	16	1.6423	1.6400	0.0023	1.6485	1.6463	0.0022
3	17	1.6423	1.6397	0.0026	1.6485	1.6460	0.0025
2	18	1.6423	1.6394	0.0029	1.6485	1.6457	0.0028
1	19	1.6423	1.6391	0.0032	1.6485	1.6454	0.0031
0**	20	1.6423	1.6388	0.0035	1.6485	1.6451	0.0034

*True (maximum) extinction angle.
**Parallel extinction. γ' is the RI along the fiber elongation axis or c-axis.

Table 10. Converting Dispersion Staining Color to Corresponding λ_m (5)

Matching Wavelength λ_m[1], nm	Particle Edge Colors[2]		Becke Line Colors[3]	
	Annular Stop[4]	Central Stop[5]	Particle	Liquid
<340	Black violet	White	White	—
<400	Dark violet	Pale yellow	Pale yellow	—
430	Violet	Yellow	Pale yellow	—
455	Blue	Golden yellow	Yellow	Violet
485	Blue-green	Orange	Orange	Violet
520	Green	Red purple	Orange-red	Violet-blue
560	Yellow-green	Purple	Red-orange	Blue-violet
595	Yellow	Deep blue	Red	Blue
625	Orange	Blue-green	Faint red	Blue
660	Red-brown	Light blue-green	—	Blue-green
700	Dark red-brown	Pale blue-green	—	Pale blue-green
1500	Black-brown	Very pale blue-green	—	Very pale blue-green

[1]λ_0 in original table. [2]In focus.[3]On focusing up. [4]Observed on a brightfield. [5]Observed on a darkfield.

Table 11. Available λ_m and t to Asbestos RI Conversion Tables*

Asbestos	RI	DRIMMC	Cargille
Chrysotile	α	1.546 (HD-L)	1.545 (E)
	α and γ	1.550 (HD-S or L)	1.550 (E)
	γ	1.560 (HD-L)	1.560 (E)
Amosite	α	1.680 (HD-L)	1.680 (B)
	γ	1.700 (HD-L)	1.700 (B)
Crocidolite	α	1.700 (HD-L)	1.700 (B)
	γ	1.680 (HD-L)	1.680 (B)
Tremolite	α	1.605 (HD-L)	1.605 (E)
	γ	1.635 (HD-L)	1.635 (E)
	α and γ	1.620 (HD-L)	1.620 (E)
	α and γ	1.625 (HD-L)	1.625 (E)
Actinolite	α	1.605 (HD-L)	1.605 (E)
	γ	1.640 (HD-L)	1.640 (E)
	α and γ	1.620 (HD-L)	1.620 (E)
	α and γ	1.625 (HD-L)	1.625 (E)
Anthophyllite	α	1.605 (HD-L)	1.605 (E)
	γ	1.635 (HD-L)	1.635 (E)
	α and γ	1.620 (HD-L)	1.620 (E)
	α and γ	1.625 (HD-L)	1.625 (E)

*Download conversion tables by scanning the QR code at the end of this paper.

Table 12. Choice of Cargille Glass Set and Lot Number for RI Liquid Calibration

Nominal Liquid RI[1]	Nominal Glass RI[2]	M-7 Set	M-24 Set	M-25 Set	Remarks
1.550	1.550	C	D	D	M-24 and M-25 are the same.
1.605	1.600	B	C	C	All three sets are the same.
1.605	1.610	D	E	E	M-7 and M-24 are the same[3].
1.610	1.610	D	E	E	M-7 and M-24 are the same[3].
1.615	1.620	D	D	D	All three sets are the same.
1.620	1.620	C	D	D	M-24 and M-25 are the same.
1.625	1.625	B	C	C	M-24 and M-25 are the same.
1.630	1.625	B	C	C	M-24 and M-25 are the same.
1.635	1.640	C/D	D	C/D	M-7 and M-25 are the same[3].
1.640	1.640	C/D	D	C/D	M-7 and M-25 are the same[3].
1.680	1.680	C	C/D	C/D	All three sets are the same.
1.700	1.700	C	C/D	C/D	M-24 and M-25 are the same.

[1]On the bottle label. [2]On the vial label. [3]With different lot numbers.

Table 13. Calibration of DRIMMC 1.550 (HD-S or HD-L) Using Cargille Glass 1.55

λ_m	M7 Lot C (n_D = 1.55158)							M24 / M25 Lot D (n_D = 1.54801)						
(nm)	17° C	19° C	21° C	23° C	25° C	27° C	29° C	17° C	19° C	21° C	23° C	25° C	27° C	29° C
400	1.517	1.518	1.519	1.520	1.521	1.522	1.523	1.515	1.516	1.517	1.518	1.519	1.520	1.521
420	1.523	1.524	1.525	1.526	1.527	1.528	1.529	1.521	1.522	1.523	1.524	1.525	1.526	1.527
440	1.528	1.529	1.530	1.531	1.532	1.533	1.534	1.525	1.526	1.527	1.528	1.529	1.530	1.531
460	1.532	1.533	1.534	1.535	1.536	1.537	1.538	1.529	1.530	1.531	1.532	1.533	1.534	1.535
480	1.535	1.536	1.537	1.538	1.539	1.540	1.541	1.532	1.533	1.534	1.535	1.536	1.537	1.538
500	1.538	1.539	1.540	1.541	1.542	1.543	1.544	1.535	1.536	1.537	1.538	1.539	1.540	1.541
520	1.541	1.542	1.543	1.544	1.545	1.546	1.547	1.538	1.539	1.539	1.540	1.541	1.542	1.543
540	1.543	1.544	1.545	1.546	1.547	1.548	1.549	1.540	1.541	1.542	1.543	1.544	1.545	1.546
560	1.545	1.546	1.547	1.548	1.549	1.550	1.551	1.542	1.543	1.544	1.545	1.546	1.547	1.548
580	1.547	1.548	1.549	1.550	1.551	1.552	1.553	1.543	1.544	1.545	1.546	1.547	1.548	1.549
589	1.548	1.549	1.550	1.551	1.552	1.553	1.554	1.544	1.545	1.546	1.547	1.548	1.549	1.550
600	1.549	1.549	1.550	1.551	1.552	1.553	1.554	1.545	1.546	1.547	1.548	1.549	1.550	1.551
620	1.550	1.551	1.552	1.553	1.554	1.555	1.556	1.546	1.547	1.548	1.549	1.550	1.551	1.552
640	1.551	1.552	1.553	1.554	1.555	1.556	1.557	1.548	1.549	1.550	1.551	1.552	1.553	1.554
660	1.553	1.554	1.555	1.556	1.557	1.558	1.559	1.549	1.550	1.551	1.552	1.553	1.554	1.555
680	1.554	1.555	1.556	1.557	1.558	1.559	1.560	1.550	1.551	1.552	1.553	1.554	1.555	1.556
700	1.555	1.556	1.557	1.558	1.559	1.560	1.561	1.551	1.552	1.553	1.554	1.555	1.556	1.557
720	1.556	1.557	1.558	1.559	1.560	1.561	1.562	1.552	1.553	1.554	1.555	1.556	1.557	1.558
740	1.557	1.558	1.559	1.560	1.561	1.562	1.563	1.553	1.554	1.555	1.556	1.556	1.557	1.558
760	1.557	1.558	1.559	1.560	1.561	1.562	1.563	1.553	1.554	1.555	1.556	1.557	1.558	1.559
780	1.558	1.559	1.560	1.561	1.562	1.563	1.564	1.554	1.555	1.556	1.557	1.558	1.559	1.560
800	1.559	1.560	1.561	1.562	1.563	1.564	1.565	1.555	1.556	1.557	1.558	1.559	1.560	1.561

Table 14. Calibration of Cargille 1.550 (E) Using Cargille Glass 1.55

λ_m	M7 Lot C (n_D = 1.55158)							M24 / M25 Lot D (n_D = 1.54801)						
(nm)	17° C	19° C	21° C	23° C	25° C	27° C	29° C	17° C	19° C	21° C	23° C	25° C	27° C	29° C
400	1.518	1.519	1.520	1.521	1.522	1.523	1.524	1.516	1.517	1.518	1.519	1.520	1.521	1.522
420	1.523	1.524	1.525	1.526	1.527	1.528	1.529	1.521	1.522	1.523	1.524	1.525	1.526	1.527
440	1.528	1.529	1.530	1.531	1.532	1.533	1.534	1.525	1.526	1.527	1.528	1.529	1.530	1.531
460	1.532	1.533	1.534	1.535	1.536	1.537	1.538	1.529	1.530	1.531	1.532	1.533	1.534	1.535
480	1.535	1.536	1.537	1.538	1.539	1.540	1.541	1.532	1.533	1.534	1.535	1.536	1.537	1.538
500	1.538	1.539	1.540	1.541	1.542	1.543	1.544	1.535	1.536	1.537	1.538	1.539	1.540	1.541
520	1.541	1.542	1.543	1.544	1.545	1.546	1.547	1.538	1.539	1.540	1.541	1.542	1.543	1.544
540	1.543	1.544	1.545	1.546	1.547	1.548	1.549	1.540	1.541	1.542	1.543	1.544	1.545	1.546
560	1.545	1.546	1.547	1.548	1.549	1.550	1.551	1.542	1.543	1.544	1.545	1.546	1.547	1.548
580	1.547	1.548	1.549	1.550	1.551	1.552	1.553	1.543	1.544	1.545	1.546	1.547	1.548	1.549
589	1.548	1.549	1.550	1.551	1.552	1.553	1.554	1.544	1.545	1.546	1.547	1.548	1.549	1.550
600	1.549	1.550	1.550	1.551	1.552	1.553	1.554	1.545	1.546	1.547	1.548	1.549	1.550	1.551
620	1.550	1.551	1.552	1.553	1.554	1.555	1.556	1.546	1.547	1.548	1.549	1.550	1.551	1.552
640	1.551	1.552	1.553	1.554	1.555	1.556	1.557	1.548	1.549	1.550	1.551	1.551	1.552	1.553
660	1.553	1.554	1.555	1.555	1.556	1.557	1.558	1.549	1.550	1.551	1.552	1.553	1.554	1.555
680	1.554	1.555	1.556	1.557	1.558	1.559	1.560	1.550	1.551	1.552	1.553	1.554	1.555	1.556
700	1.555	1.556	1.557	1.558	1.559	1.560	1.561	1.551	1.552	1.553	1.554	1.555	1.556	1.557
720	1.556	1.557	1.558	1.559	1.560	1.561	1.562	1.552	1.553	1.554	1.555	1.556	1.557	1.558
740	1.557	1.558	1.558	1.559	1.560	1.561	1.562	1.552	1.553	1.554	1.555	1.556	1.557	1.558
760	1.557	1.558	1.559	1.560	1.561	1.562	1.563	1.553	1.554	1.555	1.556	1.557	1.558	1.559
780	1.558	1.559	1.560	1.561	1.562	1.563	1.564	1.554	1.555	1.556	1.557	1.558	1.559	1.560
800	1.559	1.560	1.561	1.562	1.563	1.564	1.565	1.555	1.556	1.557	1.558	1.559	1.560	1.561

Table 15. Parameters (n_D and Dispersion Coefficient) of DRIMMC and Cargille Liquids-Glass Combination Used in the Calculations of Lookup Conversion Tables

Liquid	Dispersion Coefficient		Glass	M-7 Set*			M-24 Set*			M-25 Set*		
n_D	DRIMMC	Cargille	ID	Lot	n_D	D.C.	Lot	n_D	D.C.	Lot	n_D	D.C.
1.545		0.0264	1.55	C	1.55158	0.01112	D	1.54801	0.01197	D	1.54801	0.01197
1.546	0.0266[a]		1.55	C	1.55158	0.01112	D	1.54801	0.01197	D	1.54801	0.01197
1.550	0.0274[b]	0.0267	1.55	C	1.55158	0.01112	D	1.54801	0.01197	D	1.54801	0.01197
1.550	0.0272[c]	0.0280	1.55	C	1.55158	0.01112	D	1.54801	0.01197	D	1.54801	0.01197
1.605	0.0313[d]	0.0243	1.61	D	1.61064	0.01076	E	1.61064	0.01076	E	1.61064	0.01076
1.610	0.0315[d]	0.0251	1.61	D	1.61064	0.01076	E	1.61064	0.01076	E	1.61064	0.01076
1.615	0.0318[d]	0.0259	1.62	C	1.61998	0.01708	D	1.62048	0.01708	D	1.62048	0.01708
1.620	0.0322[d]	0.0267	1.62	C	1.61998	0.01708	D	1.62048	0.01708	D	1.62048	0.01708
1.625	0.0325[d]	0.0275	1.625	B	1.62564	0.01759	C	1.62527	0.01756	C	1.62527	0.01756
1.630	0.0327[d]	0.0283	1.63	B	1.62564	0.01759	C	1.62527	0.01756	C	1.62527	0.01756
1.635	0.0331[d]	0.0291	1.64	C/D	1.64333	0.01343	D	1.63992	0.01066	C/D	1.64333	0.01343
1.640	0.0334[d]	0.0299	1.64	C/D	1.64333	0.01343	D	1.63992	0.01066	C/D	1.64333	0.01343
1.680	0.0361[a]	0.0348	1.68	D	1.67766	0.01223	C/D	1.67827	0.01226	C/D	1.67827	0.01226
1.680	0.0383[b]	0.0348	1.68	D	1.67766	0.01223	C/D	1.67827	0.01226	C/D	1.67827	0.01226
1.700	0.0378[b]	0.0370	1.70	C	1.70136	0.01709	C/D	1.70207	0.01710	C/D	1.70207	0.01710

*There is overlapping among the three sets of glasses. Different set and/or lot number may have the same n_D and dispersion coefficient.
[a]HD, [b]HD-L, [c]HD-S, [d]Average of HD and HD-L

Table 16. Form for Recording RI Liquid Calibration Results Using Cargille Glass Standards (18)

Date	RI Liquid Label	M-Set Cargille Glass Label		CSDS Observation of Glass		Liquid Temperature	Calibrated RI of Liquid	Absolute Difference	**A**ccept or **R**eject	Initials of Analyst
	RI Value	RI value	Lot No.	Color	λ_m (nm)	t (°C)	$n_D^{25°\,C}$	8–2		
1	2	3	4	5	6	7	8	9	10	11
									A R	
									A R	
									A R	

1. Date.
2. The $n_D^{25°\,C}$ on the label of the RI liquid bottle.
3. The RI value on the label of Cargille glass vial (fill in the Set ID: 7, 24, or 25).
4. The lot number on the label of Cargille glass vial.
5. The predominant central stop dispersion staining color displayed by glass fragments.
6. The matching wavelength, λ_m, corresponding to the observed CSDS color in Column 5.
7. The temperature of the RI liquid or the room temperature if in equilibrium.
8. The reading based on the values in Columns 6 and 7 from the lookup conversion table for the liquid-glass combination, $n_D^{25°\,C}$, the calibrated RI of the liquid at 589 nm and 25° C.
9. Column 8 minus Column 2.
10. If the *absolute* value of Column 9 is less or equal to 0.004, circle A for *acceptable*; otherwise, circle R for *rejected*.
11. Analyst's initials.